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PROMOTION OF SAFETY IN THE TRANSPORTATION OF EXPLOSIVES AND OTHER DANGEROUS ARTICLES IN THE UNITED STATES.

BY

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[This paper describes the past and present methods of transporting explosives and other dangerous articles on railroads. Reference is made to numerous fatal accidents which have occurred, due to the careless handling of dangerous freight. The origin, organization and work of the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, and its co-operation with railways and shippers is reviewed. Consideration is given to the necessity for uniform regulations for the transportation of explosives, inflammable materials, acids, etc.]

WHILE it is becoming increasingly difficult for one mind to keep abreast in one specialty of the large store of information made available by modern facilities for disseminating knowledge, yet all who would be useful citizens must take active interest in any problem that affects national interests so closely as does the promotion of safety in the transportation of dangerous articles. Upon us rests an obligation to learn

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not only what is being done to secure a solution of this problem by those upon whom the responsibility rests directly, but what we can do to assist the work.

The dangerous articles referred to are those possessing chemical or physical characteristics that are liable to cause fires, or explosions, under the conditions incident to their transportation by railways. Such an article carries its risk from its compounding to its expenditure in doing useful work. This risk can be minimized, but it cannot be avoided; and the chances for accident increase with the number of human equations involved in the handling. Insurance can do no more than distribute the burden.

In the manufacture, transportation, storage, or use of these dangerous articles, the ignorance, or the indifference, of one individual may sacrifice the interests of many. The education of the railway employee is the more difficult, since his handling of a dangerous article is occasional and of short duration while the duty of the employee in manufacture, storage, or use, is more permanent.

Since an abnormal risk, due to improper manufacture, or to insecure packing, cannot be made normal by subsequent care in handling, a dual responsibility to the public rests upon the shipper and the carrier.

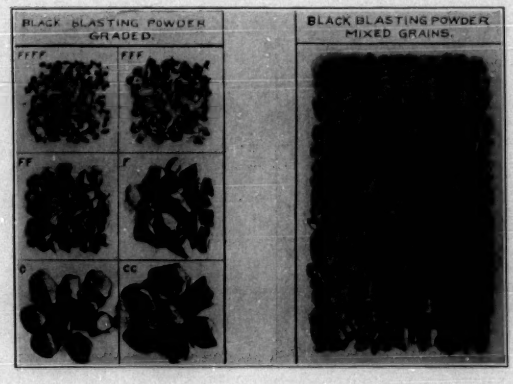
An unhealthy railway competition for freight encourages a shipper to economize in packing at the expense of safety; and even a conscientious shipper will hesitate to spend money voluntarily for what he may acknowledge to be necessary packing when his competitors are free to use a cheaper package.

To minimize these difficulties, the railroads of the United States and Canada are represented in an association known as the "Bureau for the Safe Transportation of Explosives and Other Dangerous Articles," organized under the auspices of the American Railway Association. This Bureau was created primarily to promote the safe transportation of explosives, and as a direct result of the explosion of a carload of dynamite on the Pennsylvania Railroad near Harrisburg in May, 1905. The application of emergency brakes to a freight train caused it to buckle, and a car loaded with a low grade of dynamite was deflected to the adjoining track in front of a fast passenger train. The dynamite was exploded by the collision and the

explosion was followed by fire in the overturned cars. Nineteen people were killed, one hundred and eighty-five were injured, and the accident cost the Pennsylvania Railroad about $650,000.

As explosives cannot be safeguarded without protecting them from fire, and inflammable articles cause fires, the Bureau was required to prepare suitable regulations for the transportation of all kinds of dangerous articles, and then to furnish the inspection service necessary to enforce compliance with these rules by shippers and railway employees.

FIG. 1.



Black powder granulation.

It is important to appreciate that while this concerted effort of the railways promised some decrease in their damage claims, it promised a more important economy of life, and a relief to the minds of railway officials anxious to discharge their full duty to the public. It was a contribution to the public welfare not required by any State or Federal laws and offered by men who are too frequently subjected by the public to unmerited criticism.

It is surprising that prior to the organization of this Bureau so little effective attention was given by legislators to the transportation of explosives and other dangerous articles. The

Bureau became active in June, 1907, when there existed an obstructive Federal statute of 1866 with which it was impossible to comply. It had been disregarded consistently and in spite of the severe penalties imposed by it. By securing the confidence and co-operation of the manufacturers of explosives, the railways prepared and published a reasonable set of regulations for the transportation of explosives, and then presented so forcibly to Congress the necessity for a revision of Federal legislation that the act of May 30, 1908, was passed. This law invested the Interstate Commerce Commission with the power to prescribe such regulations for interstate traffic and, after a public hearing, the Commission adopted without material modification the rules prepared by the Bureau.

It is instructive to note the unusual origin of this law. It was not drawn by a legislator possessing no special knowledge of explosives and inclined under the influence of excitement caused by some disastrous explosion, to apply drastic, even if impractical, remedies. It was prepared by naturally antagonistic elements, shippers and carriers, each technically well informed as to the characteristics of explosives and alive to its own interests, while amenable to reason and appreciative of the necessity for joint action to promote safety of the public. It is frequently assumed that railway and other large corporations are opposed to all kinds of governmental regulation. Here was a joint request for such regulations submitted to the national legislature by representatives of all of the railways and of the large manufacturers of explosives, including the company sometimes described as the "powder trust."

ORIGIN OF BUREAU OF EXPLOSIVES.

The Pennsylvania Railroad has always had more factories of explosives on its lines and more of this dangerous traffic to handle than any other railway. The following statement shows the principal accidents whose cumulative effect on the minds of the Pennsylvania Railroad Officials caused Mr. James McCrea to suggest to the American Railway Association in April, 1905, the advisability of appointing a special committee to draft regulations for the safe transportation of explosives and with a view to their adoption and enforcement by all members of that association:

COMPILATION OF SERIOUS ACCIDENTS IN TRANSPORTATION OF EXPLOSIVES OR OTHER DANGEROUS ARTICLES, PRIOR TO NOVEMBER, 1905, RECORDED BY THE BUREAU OF EXPLOSIVES.

Kind of explosive, etc.	Bureau number	Place and date	Killed	Injured	Known property loss
Black Powder	19–575	Winchester, Ky. Aug. 19, 1881	2	8	.....
Black Powder	19–C–1	Kings Mills, Ohio. July 15, 1890	10	18	$180,000.00
Black Powder	19–C–2	Lawrence, Ohio. Oct. 5, 1893	..	3	10,000.00
Black Powder	19–C–3	Greensboro, N. C. Oct. 9, 1893	..	...	7,245.00
Black Powder	19–576	Lawrence, Ohio. Oct. 9, 1893	..	4	.....
Black Powder	19–655	Baychester, N. Y. Oct. 24, 1903	..	...	.....
Black Powder	19–C–4	Redstone Junc., Cal. Dec. 24, 1903	..	...	.....
Dynamite	19–C–5	Forest, Ohio. Sept. 19, 1887	2	2	16,000.00
Dynamite	19–669	Bowie, Texas. April 5, 1901	..	...	15,000.00
Dynamite	19–635	Pearisburg, Va. July 17, 1903	2	16	.....
Dynamite	19–638	Beaumont, Kas. Sept. 10, 1903	3	2	.....
Dynamite	19–C–6	Bay City, Mich. Sept. 13, 1903	2	2	7,500.00
Dynamite	19–78	Crestline, Ohio Nov. 1, 1903	..	4	28,000.00
Dynamite	19–C–7	Greenwood, Del. Dec. 2, 1903	1	32	24,514.55
Dynamite	19–609	Fallon, La. March 21, 1905	1	2	.....
Dynamite	19–5	Harrisburg, Pa. May 11, 1905	19	185	643,203.81
Dynamite	19–661	Council Bluffs, Ia. 1880	..	...	.....
Matches	19–652	Tyler, Texas. Aug. 1, 1902	..	...	1,000.00
Oil	19–607	Mystic Junc., Mass. July 12, 1900	5	...	.....
Rack-a-Rock (High Explosive)	19–657	Tarrytown, N. Y. 1890 or 1891	14	...	.....
			61	278	$932,463.36

Total killed..... 61
Total injured..... 278
Total known property loss.... $932,463.36

Nearly twenty years previous to Mr. McCrea's proposal the Pennsylvania Railroad had prescribed for this traffic, regulations prepared under the supervision of its Chief Chemist, the late

Doctor Charles B. Dudley. As a rule, other lines had no special regulations in force and even on the Pennsylvania Railroad there was no technical inspection service previous to 1905 to enforce compliance with its rules.

The necessity for the prompt interchange of cars at junction points made it necessary for the line receiving a car loaded with explosives to assume all the risks due to possible defects in the manufacture or packing of the explosive, the preparation

FIG. 2.

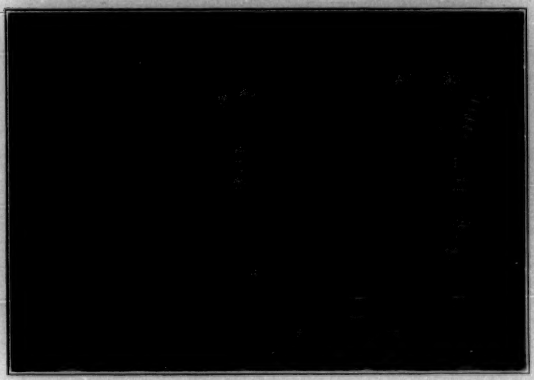
Black powder shipping can—screw top.

or loading of the car. Assuming the presence of serious defects, it was apparent that the exercise of exemplary care in handling the car in transit could not materially reduce the chances for an accidental explosion, and when it occurred an innocent line was liable to be the victim.

The railroads were face to face with an "explosive" problem that had come gradually into prominence through the growth of a demand for explosives in prosecuting various industries. For example, we learn from the Geological Survey that the total amount of coal mined in the United States during each of the last three decades has equalled the total mined in this country

up to the beginning of that decade. Phenomenal increases have also taken place in other mining industries. The driving of tunnels, the blasting for foundations and for building stone, have scarcely kept ahead of the development of new uses for explosives, even in agriculture. The farmer needs them now to clear his land of stumps and bowlders, to dig holes for transplanting trees, and even to break up a subsoil that he cannot plow. All of the guns on a modern dreadnought, fired at their maximum rate, would expend explosives at the rate of about 6000 pounds per minute.

FIG. 3.



Defective cans.

About five hundred million pounds of explosives are produced annually in the United States and for their transportation about 5000 freight cars are in constant use. If these cars were distributed uniformly over the railway mileage of the country, a passenger would be carried within a few feet of one twice for every hundred miles travelled, and many of these cars have a greater capacity for destruction of life and property than attaches to some of the storage magazines that are so willingly shunned by those living in their vicinity.

The American Railway Association appointed the special

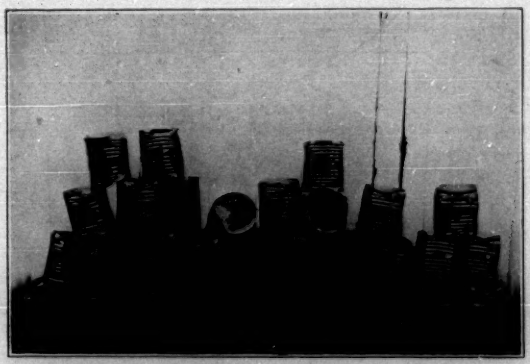
committee suggested by Mr. McCrea and, as if to emphasize the necessity for its labors, that unfortunate explosion occurred at Harrisburg in May, 1905. The Committee with Mr. McCrea as Chairman, Doctor Dudley and other prominent railway officials as members, worked assiduously on this problem during the summer of 1905, employing chemical experts and consulting freely with representatives of the War and Navy Departments of the Federal Government. Its draft of regulations for the safe transportation of explosives was approved by the Association in November, 1905, and these regulations were prescribed promptly thereafter by individual lines for the guidance of their shippers and employees. This was the first essential step toward a great reform, but it accomplished little for the reason that regulations do not enforce themselves and these were so technical that they soon found their way to the top shelf of the busy freight agents file of circulars.

The Pennsylvania Railroad employed an Inspector of Explosives immediately after the Harrisburg accident and he was kept travelling over its lines instructing shippers and railway employees in the requirements of the rules and checking their violations of them. Later on, one or two other lines followed this excellent example. In November, 1905, Mr. McCrea, as Chairman of the special committee which has since become one of the most important standing committees of the American Railway Association, recommended the organization of the present Bureau of Explosives to provide for all roads an extension of the educational and inspection work that had proved so useful on his line. A Constitution and By-laws for the Bureau were presented and approved. In the spring of 1907 the Secretary of War, now the President of the United States, was asked to co-operate by detailing an ordnance officer of the army to take charge as Chief Inspector of the practical work of the local inspectors. This request was granted after an extended discussion that emphasized the obligation of the Federal Government, the principal shipper of explosives, to assist in safeguarding the public from the danger of repetitions of the Harrisburg accident.

GROWTH OF BUREAU WORK.

In June, 1907, the Bureau membership comprised 78 railway companies operating 130,026 miles of track. Under the scheme provided, the local inspectors, assigned to duty on several lines, occupied a novel position in railway administration. They were not actually invested with any disciplinary authority but they exercised it indirectly and in proportion to the approval of their recommendations by the operating officials. A successful inspector must have an accurate knowledge in detail of railway

FIG. 4.



Black powder cans in car test.

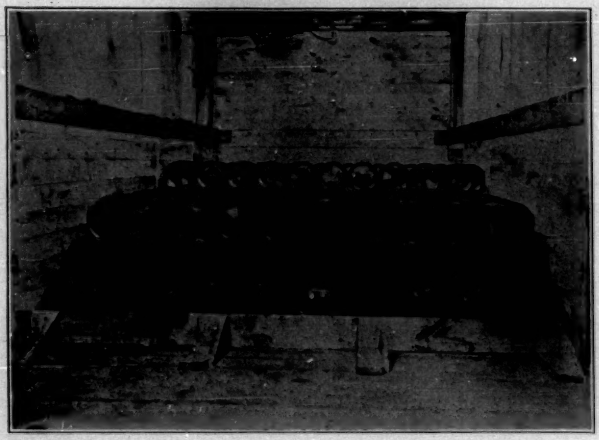
operation and a practical knowledge of explosives; he must know the regulations thoroughly and, above all, he must have tact, self-control and good judgment.

Starting in August, 1907, with a small group of four, the force now comprises 21 local inspectors who cover the railway territory of the United States and Canada. The railway membership of the Bureau has increased to 173 companies operating 222,629 miles of track.

The task set for the Executive Committee and the Chief Inspector by the conditions found to exist was sufficiently difficult. The manufacturing shippers regarded the Bureau with

suspicion and one of them did not hesitate to express the conviction that it represented only a concealed move in the interests of the large powder corporation. Traffic officials of the shippers and of the railways were naturally opposed to any restrictions on the volume and movement of traffic. Operating officials of railways gave their support but they were uncertain of the success of the novel experiment which amounted almost to a centralized management of a railway specialty. Any serious mistake

FIG. 5.



End car load black powder.

in policy, or administration, would have resulted probably in the abandonment of the Bureau as an unsuccessful experiment.

The manufacturers of explosives were admitted to conferences and invited to discuss all proposed rules and amendments. It was announced that "a rule which cannot be successfully demonstrated to be reasonable and practical will not be approved by the Bureau." These manufacturers are now associate members of the Bureau and they contribute to its maintenance. They are the best inspectors we could have to enforce the rules in their own works.

Manufacturers of other classes of dangerous articles, drugs, acids, friction matches, charcoal, etc., are being induced to co-operate with the Bureau in a similar way. In all cases our effort is to locate the real causes of accidents and then to find the most direct road to a remedy, such as separation of drugs that react on each other chemically to produce fire, use of incombustible packing material for nitric acid instead of untreated excelsior, a stronger and more air-tight box for friction matches, sufficient air cooling of charcoal before loading into cars, etc.

FIG. 6.

Full end car load black powder.

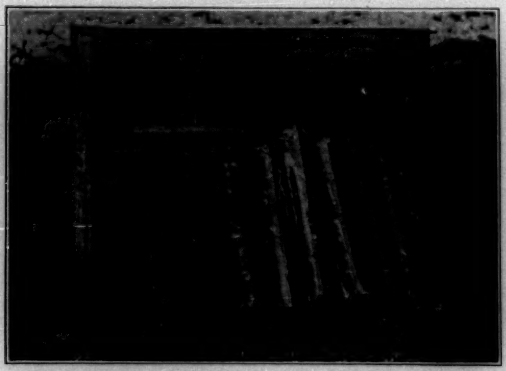
It is encouraging to note the spread of this movement to Canada where the principal railroads are members of the Bureau and our regulations for the transportation of explosives have been adopted by the Board of Railway Commissioners.

BUREAU OPERATION.

The twenty-one local inspectors are assigned to geographical districts and work in the interests of all railway members in their respective districts. After inspection of a railway station,

during which the records of the station are examined and the methods of inspecting, billing, handling, and loading dangerous freight are observed, the faults discovered are checked on a blank form, which shows all the faults that could be committed. Copies of this report are furnished by the inspector to the agent, to the general manager of the road and to the chief inspector of the Bureau. If subsequent inspections fail to show satisfactory conditions, or a marked improvement, a special report is made to the general manager recommending disciplinary action.

FIG. 7.



Dynamite cartridges.

Similar blank forms are used to report inspection of manufacturing plants, cars loaded with explosives, and storage magazines from which shipments of explosives by rail are made. When explosives are found in such magazines not in proper condition for safe transportation, they are condemned by the inspector and a written promise not to ship them by rail is exacted from the owner, or caretaker, of the magazine. Copies of this agreement with description of the condemned packages are furnished all adjacent station agents (see pages 177 and 178).

The proverbial "ounce of prevention" has an enhanced value when applied to the handling of dangerous articles. Copies of

B. E. Form 10. 12-27-09-5M.

BUREAU OF EXPLOSIVES.

VIOLATIONS OF REGULATIONS, observed at

Newton, N. Y. Station

John Doe, Agent

Inspected by Richard Roe, Local Inspector

During Inspection of N. Y. Terminal Division

N. Y. & Conn. R. Y.

Date of Inspection 191

Note.—Violations checked √ have been found on this Inspection and the original of this report left with Agent, who will retain it and exhibit on succeeding Inspections; a copy will be sent to Chief Inspector and also to proper Railway Officials. Numbers in parenthesis ( ) refer to I. C. C. Regulations.

1. Packages of Explosives showing signs of exudation have been accepted for shipment. (1532)		10. a. Shipments from connecting lines are not inspected before acceptance.	
2. Forbidden, condemned or defective packages of Explosives have been accepted for shipment. (D. E. & F.) (1531 to 1536)		b. Shipments which do not comply with regulations are accepted from connecting water lines. (1670)	√
3. Explosives are not properly loaded or stayed in cars. (1674 to 1683)	√	11. Proper certificates on shipping orders are not required from shippers. (1668)	
4. a. Cars are not properly prepared or inspected before loading. (1662)	√	12. Station has not proper supply placards and certificates.	
b. Certificate of Inspection is not required. (1665)	√	13. a. Shipping orders bearing certificates are not properly filed.	
5. a. Cars are not properly placarded "Explosives."		b. Way-bills are not properly endorsed. (1668, 1669)	
b. Cars are not properly placarded "Inflammables."		14. Way-bills do not properly describe shipments. (1668)	√
c. Certificates of inspection are not attached to each side of cars. (1666, 1663, 1663)	√	15. Regulations are not on file.	
6. Cars are not placed properly in train. (1686)		16. Regulations have not been furnished to shippers. (1696)	√
7. Cars of less than 60,000 lbs. capacity are used. (1662a)		17. Prompt removal of explosives is not enforced. (1672)	
8. Placards are not removed from cars after unloading. (1696)		18. Employes are not specially instructed. (General Notice.)	√
9. Explosives are not handled carefully. (1671, 1672)		19. a. Violations of regulations discovered in cars are not reported.	
		b. Reports are not made of damaged packages of explosives discovered. (G.)	

Indicate Character of Business			Number of cars required per week		Storage on Railway property	
			C. L.	L. C. L.	Average time	Exception
	Forwarding	√				
	Receiving	√	---	2	24 hrs.	None
	Transfer					
	Interchange	√	Shipping days:		Tues. & Thurs.	

Description of storage facilities for Explosives (packages and cars).

Storage bin in warehouse. No track storage facilities.

Fire protection; Lighting arrangement.

Hand Extinguishers - Gas lights.

Character of Explosive freight handled at this Station.

High explosives, Blasting caps and Fireworks.

B. E. Form 14-A.

BUREAU OF EXPLOSIVES.

Richard Roe, Local Inspector.

Inspection of the Magazine used by Jos. Green,

located at Newton, N. Y.,

having been made this day, and explosive material stored therein

manufactured by Acme Powder Co.

having been condemned for the reasons stated below, as not complying with the Regulations for the Transportation of Explosives, of the Interstate Commerce Commission, *it is hereby promised and agreed* that said condemned explosive material, (indicated hereon) will not be offered for shipment, or shipped by rail, except with the written consent of the Chief Inspector or a Local Inspector of the Bureau for the Safe Transportation of Explosives. The condemned material is marked and described as follows:

29 - 50 lb. cases Acme Dynamite marked:

1 1/4 x 8	G
ACME	
DYNAMITE	
40%.	
XLC - 4	B

Cartridges leaking, boxes stained with nitroglycerin; not packed with sawdust and boxes made of lumber 3/8 inch thick.

Witness: Signed Jos. Green,

Richard Roe,

Dated at Newton, N. Y. Dec. 10, 1909.

NOTE:—This agreement should be signed by proprietor of magazine, or authorized representative, and forwarded to Chief Inspector; a copy should be furnished each Railway Agent at Stations to which shipments from this magazine are liable to be offered, and a copy should be left with proprietor of magazine.

magazine inspection reports are furnished also to the makers of the stored product and these reports assist materially in keeping the manufacture of this product up to the standard.

EDUCATIONAL WORK.

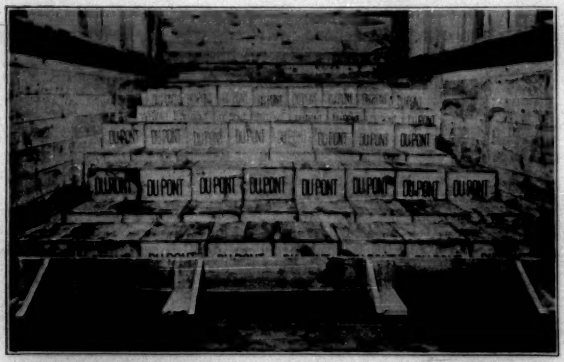
The book of regulations prepared by the Bureau contains about 25,000 words. The subjects treated are technical, and careful reading and study are necessary to avoid passing over important facts and rules in the condensed paragraphs. If all the men who should be familiar with at least some of these regulations were collected in one class,—men with duties connected with the manufacture, storage or transportation of explosives, and other dangerous articles,—we should have a class of several millions. The important railway members of the class would exceed a quarter of a million. The educational difficulties are multiplied many times by the enforced separation of this class, the natural limitations to the average intelligence of its members, and the fact that, for many of the railway employees, this set of rules is only one of many others with which they must be familiar. We have to contend also with the average American's indifference to prescribed precautions, especially in the handling of explosives. With only a limited experience in the use of small arms he will handle dynamite with impunity rather than risk an insinuation against his courage. He fails, in his ignorance, to appreciate that a wholesome fear of explosives is characteristic of the brave men who are acquainted with and handle them daily.

An inspector advances the education of each railway employee and shipper that he encounters in his daily work. He attends frequently the business meetings of railway officials and employees and addresses them on the subject of the regulations. A special agent of the Bureau, provided with a well-selected set of lantern slides, covers the lines of Bureau members to deliver illustrated lectures of one and one-half to two hours' duration to railway audiences of 25 to 1500 men. These slides emphasize the destructive power of explosives and show good and bad methods for packing them and for loading packages into cars.

The following examples and explanations of these illustrations will indicate their value for the elementary instruction of railway employees (Figs. 1 and 2).

Black powder is the oldest of explosives in general use. It is relatively weak but this is an advantage where, as in the quarrying of building stone, a shattering effect is to be avoided. It is not ignited readily by friction or by blows, but is peculiarly susceptible to ignition by sparks or other sources of fire. When ignited in transit, the violence of the explosion increases with the fineness of the granulation. For this reason the grade used in rifles and shot-guns is the most dangerous. Nearly all explosions in transit have been preceded by leakage of the ex-

FIG. 8.



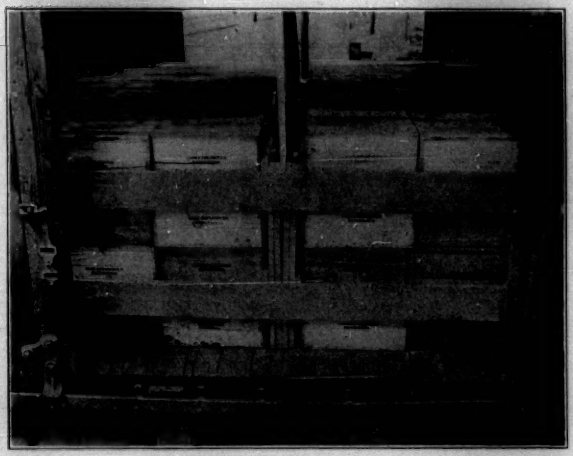
End car load dynamite.

plosive from a ruptured package, the rupture being due to defective design or manufacture of the package, to bad loading in cars, or to rough handling of the car or package. When even a thin train of black powder from a leaking package is ignited, the fire is almost sure to be carried to the source and to explode the package. Fire in a train of black powder leaking from a keg in a moving wagon has been known to travel several blocks and explode the wagon load. The burning of black powder in the sweepings from a car has caused an explosion in the car, the fire being carried along by powder dust in the air. The most important precaution for shippers and railway employees is to avoid leakage by offering and accepting respectively only

good and sound packages that will stand without rupture the ordinary shocks incident to transportation.

Screw tops, such as shown in Fig. 2, are not used as much as a slide cover that is held in place by turned-up flanges of metal. The screw top is liable to work loose when the combination of a minimum plug in a maximum top occurs. The head and side seams of the cans are sources of possible defects in construction.

FIG. 9.



Side full car load.

Illustration Fig. 3 is a photograph of cans filled with black powder, offered by a shipper, who evidenced no regard for safety of the public, and accepted by a railway agent without inspection. A casual inspection would have shown that powder was visible through open seams and holes eaten through the cans by rust. This is a good example of the old practice that has been almost entirely corrected by the activity of agents of the Bureau of Explosives.

Illustration Fig. 4 is a photograph of cans taken from a car-

load just after the car had been intentionally subjected to a coupling test at a speed in excess of the usual practice. The large volume of modern railway traffic makes it difficult to prevent the occasional rough treatment of a car. These kegs were loaded with sand for this test and the sand spilled from open seams to the floor would, under similar treatment in service, represent loose powder prepared for ready ignition by friction,

FIG. 10.

Explosive placard.

by a spark entering the car, or by grains of powder escaping from the car and falling among brake-shoe sparks.

The loading and bracing of packages should be such as to prevent their relative movement in the car during transit. Fig. 5 shows a method devised to do this at a minimum cost of labor and material. The kegs are piled to interlock, and they are arranged in steps so that the bracing of the front row will protect all the kegs against longitudinal movement. The floor brace is constructed outside the car, and the only nailing re-

quired inside is that to secure the brackets to the floor. In driving these nails there is no danger of the hammer striking a package of explosives or of having a badly directed nail penetrate one of the packages.

One end of a car bearing a maximum load of black powder (2000 kegs, 50,000 pounds of powder) and the bracing of the load are shown by Fig. 6.

As is well known, dynamite is made by mixing nitro-glycerin with an absorbent material that holds the liquid in suspension,

FIG. 11.

Old method of loading.

as a sponge holds water. In this condition the small particles of the liquid are cushioned against shock and will bear a reasonable amount of rough treatment. The absorbent is called the "dope" and is itself explosive since it consists, as a rule, of a mixture of sodium nitrate and wood meal. If, for any reason, the absorbent releases the nitro-glycerin, we not only lose the cushioning effect referred to but the liberated liquid is liable to exude through the joints of the paper cartridge and to the outside of the wooden box, where it may be ignited readily by friction or by sparks (see Fig. 7).

High storage temperatures render the liquid less viscous and facilitate its escape from the absorbent. The entrance of moisture into the hygroscopic "dope" during storage in damp magazines also tends to drive out the nitro-glycerin.

Dynamite in good condition, as it leaves the factory, may thus become dangerous through physical changes in storage and during times that are short in proportion as the factor of safety provided by the manufacturer against exudation is low. The

FIG. 12.

Engine tender.

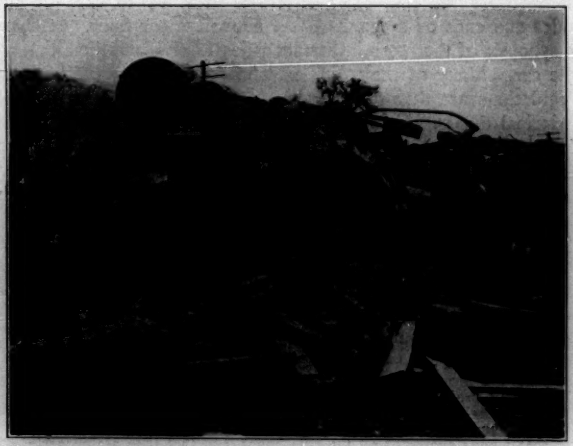
necessity for careful inspection of packages, offered for transportation after storage, is apparent. It is also evident that the cartridges will leak more readily if stored vertically and especially if subjected to the vibration of a moving car while in that position. Hence the conspicuous marking on the top of each box, "This Side Up."

A serious explosion of dynamite in transit was caused by leakage from a magazine shipment of 5000 pounds. The liquid nitro-glycerin escaped finally through the floor of the car to the

wheel and was ignited by pressure between wheel and rail. At first, only detached drops exploded with a fire-cracker noise; but finally the explosion of a number of drops that had collected while the car was at rest caused the explosion of the entire shipment at an estimated cost to the railroad of over $200,000 for life and property destroyed.

In spite of convincing circumstantial evidence that this dynamite was not in proper condition for safe transportation

FIG. 13.



Result of collision with wagon load of dynamite, B. & O. R. R.

when offered to the carrier, the shipper filed a claim against the railway for the destruction of his $600 worth of dynamite.

Fig. 8 shows application of the interlocking and step-down method to the loading of boxes of dynamite. Fig. 9 shows a side view of a maximum carload. Any lost longitudinal space is taken up by driving wooden wedges between the cribs that separate the end loads. A car containing as much as 60,000 lbs. of dynamite has been loaded by this method and transported in safety for a long distance.

These pictures help us to appreciate the serious and unwelcome responsibility that rests on the carrier of such lading through our densely populated centres. Shippers of inflammable articles that may under certain favorable conditions cause fires, such as drugs, inflammable oils and liquids, chemicals, charcoal, friction matches, and acids, should recall, when inclined to combat enforcement of the rules, that these rules are a part of the general scheme necessary for segregating and protecting the more dangerous materials.

A placard (Fig. 10), 12 x 14 inches in size and printed in conspicuous red and black letters is attached to each of the sides and ends of a car, 4½ feet above the car floor. It bears a synopsis of the more important rules for the safe handling of the car. Many of the trainmen who do not study the book of regulations are thus given frequent opportunites to learn their principal duties. Cars must be specially selected and prepared for the transportation of the more dangerous explosives. The following Car Certificate signed by representatives of the carrier and shipper, each checking the other, must be attached to each side of such a car:

CAR CERTIFICATE.

No. 1. .....STATION,.....19

I hereby certify that I have this day personally examined .....car No....., and that the roof and sides have no loose boards, holes, or cracks, or unprotected decayed spots liable to hold sparks and start a fire; that the kingbolts or draft bolts are properly protected, and that there are no uncovered irons or nails projecting from the floor or sides of the car which might injure packages of explosives; also, that the floor is in good condition and has this day been cleanly swept before the car was loaded; that I have examined all the axle boxes, and that they are properly covered, packed, and oiled, and that the air brakes and hand brakes are in condition for service.

.....

* *Railway Employe Inspecting Car.*

No. 2. 19

I hereby certify that I have this day personally examined the above car, that the floor is in good condition and has been cleanly swept, and that the roof and sides have no loose boards, holes, cracks, or unprotected decayed spots liable to hold sparks and start a fire; that the kingbolts and draft bolts are protected, and that there are no uncovered irons or nails projecting from the floor or sides of the car which might injure packages of explosives; that the explosives in this car have been loaded and stayed, and that

the car has been placarded according to paragraphs 1661, 1666, and 1674 to 1683, inclusive, of the Regulations for the Transportation of Explosives prescribed by the Interstate Commerce Commission; that the doors fit so tightly or have been stripped so that sparks cannot get in at the joints or bottom.

.....

* *Shipper or Duly Authorized Agent.*

.....

* *Railway Employe Inspecting, Loading and Staying.*

NOTE.—Both certificates must be signed. Certificate No. 1 by the representative of the carrier. For all shipments loaded by the shipper, he, or his authorized agent, and the representative of the carrier must sign certificate No. 2. When the car is not loaded by shipper certificate No. 2 must be signed only by the representative of the carrier. A shipper should decline to use a car not in proper condition.

* A. R. A. Standard Certificate, Rules 1301, 1306 and 1307.

Before offering a shipment of explosives to the carrier, the shipper must prepare it properly and his written request for its transportation, his Shipping Order, must have the following certificate:

> This is to certify that the above articles are properly described by name and are packed and marked and are in proper condition for transportation, according to the regulations prescribed by the Interstate Commerce Commission.

The explosive must be described on the shipping order under one of the following names: *Black* or *Brown Powder, High Explosives, Smokeless Powder for Cannon, Smokeless Powder for Small Arms, Fulminates, Small-arms Ammunition, Ammunition for Cannon—Explosive Projectiles, Ammunition for Cannon—Empty Projectiles, Ammunition for Cannon—Without Projectiles, Explosive Projectiles, Detonating Fuzes, Blasting Caps, Electric Blasting Caps, Primers* (naming kind), *Percussion Fuzes, Time* or *Combination Fuzes, Common Fireworks, Special Fireworks, Safety Fuse,* or *Safety Squibs.* Other explanatory terms may be added if desired for the information of consignees. For example, any compound that can be detonated by a commercial "blasting cap" must be described as "High Explosive" and, for obvious reasons, railway employees are not allowed to recognize any difference in the dangers attending the handling of the various types of high explosives. The description may

or may not show the type, as "400 Cases High Explosives (Blasting Gelatin)."

Fig. 11 shows method of loading a box of dynamite when its handling was similar to that of a box of crackers. It was not only liable to be moved in the car under coupling and other shocks but there was danger of injury to it from other packages of freight falling on or against it. In the picture, a heavy casting rests against the box of dynamite. In another case one of our inspectors found a box of dynamite acting as a chock for a heavy spool carrying a ton of lead covered cable. A

FIG. 14.

Oklahoma magazine.

contrast of this picture with the previously illustrated methods for orderly loading and bracing of these dangerous packages will indicate some of the reforms resulting from the work of the Bureau.

Fig. 12 shows an actual occurrence due to carelessness of the engineer of a shifting engine. The almost miraculous escape from an explosion of this and three other cars in the vicinity, each carrying over 20,000 pounds of dynamite, was due largely to the fact that the dynamite was in a frozen state. When completely frozen, dynamite is less sensitive than usual to shock, and in a partially thawed state it is more sensitive.

Fig. 13 reproduces an old photograph and gives some idea of what happened when the engine of a freight train struck a wagon containing 950 pounds of dynamite.

Fig. 14 shows effect on a freight train, 200 feet away, when a magazine containing about 19,000 pounds of dynamite was exploded by lightning. Not the least important feature of our work has been an agitation of the danger involved in locating storage magazines too close to railway tracks and inhabited build-

FIG. 15.

Black-powder-projectile fragmentation.

ings. The manufacturers of the powder stored in such magazines are co-operating heartily with us to secure removal of these hazards as rapidly as possible.

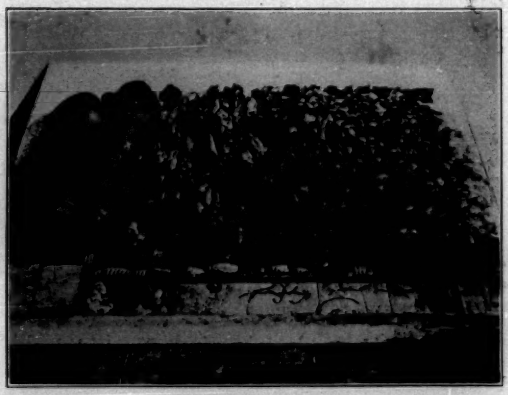
One method, frequently used in the military service, to determine the relative strength and especially the quickness of an explosive, is to explode loaded projectiles and examine the size and number of fragments. Black powder breaks a 1000-pound projectile into a small number (30–50) of large pieces (Fig. 15); a high explosive of medium strength and quickness (Fig. 16) yields about 1000 pieces, the average weight of one pound being

quite satisfactory for attack of the enemy's personnel and material; and a powerful, quick explosive, such as picric acid, or explosive gelatin (Fig. 17), converts the projectiles almost into metallic grains and dust, too small to cause serious injury to material.

Fig. 18 illustrates the force exerted by 135 pounds of a high explosive, of medium strength, exploded in a 1000-pound projectile, suspended three feet under the surface of the water.

Figs. 19 and 20 show the effect on a 12-inch gun, weight

FIG. 16.



High-explosive-projectile fragmentation.

52 tons, of the premature explosion in the bore, of a shell loaded with 180 pounds of explosive gelatin. This experiment was made against the advice of military experts and cost the Government considerably more than $50,000.

The tendency of inexperienced men to become over-confident in handling explosives is well illustrated by Fig. 21. An enthusiastic inventor constructed a special gun to fire shell loaded with dynamite and claimed to have used it successfully on occasions when his friends and members of his own family were allowed to stand near it. When the gun was tested by experts

the inventor objected to what he considered the unjust insinuation involved in asking him to take cover. He was very much pleased afterwards that he had been forced to do so.

INFLAMMABLE ARTICLES.

Regulation of the transportation of inflammable articles, compressed gases and acids, is necessary to the safeguarding of explosions in transit. Indeed, it is quite possible for some inflammable articles to form true explosive mixtures during

FIG. 17.

Powerful, quick-explosive-projectile fragmentation.

transit. An explosion is only a means for making a fire quickly, the necessary oxygen to burn the combustible matter being furnished by the chemical compound instead of by a draught of air. When the combustible vapors of such a liquid as gasolene are mixed with air in equivalent proportions we obtain a true explosive of great power. Such a mixture containing a pound of gasolene vapor is much more powerful than a pound of dynamite, though not capable of as much condensation or of generating such a high local pressure.

The foundation for disaster in transit of inflammables, as

of explosives, is laid by a leakage of contents from shipping containers. To minimize this leakage, the packages must be well designed and made, and they must be handled carefully and intelligently. Both the shipper and the carrier have independent duties to perform and a failure of either may sacrifice safety.

The regulations classify these articles under definitions illustrated by numerous examples, tell how different substances must

FIG. 18.

Water mine.

be packed, marked and labelled, and require the shipper to furnish over his signature on his shipping order, a certificate of his compliance.

The various labels that shippers must furnish and attach to those packages that require a label are reproduced below in reduced size. These labels are of diamond shape, diagonals 5¾ inches long, and of distinctive colors (see Figs. 22, 23, 24, 25, and 26).

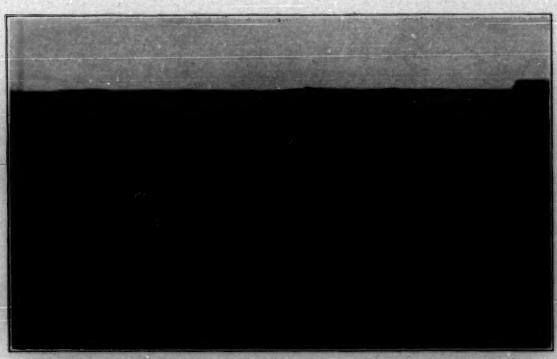
A car that contains one or more packages protected by a red,

or yellow, label must carry on both sides and ends an "Inflammable Placard" of diamond shape (Fig. 27), 15 inches long, printed in conspicuous red and black letters.

Many of the fires due to leaking shipments of inflammable liquids would be avoided by compliance with the second rule printed on the placard. The regulations are designed to minimize the chances for leakage and even when it occurs to prevent fire.

In August, 1907, a car at Kingston, N. Y., contained a leaking shipment of rubber cement and it bore no warning placard.

FIG. 19.



Railway employees entered it at night with a lighted lantern to transfer the shipment and the lantern flame ignited the mixture of gasolene vapor and air. The resulting fire consumed the station and about 40 cars of merchandise, causing a loss of about $140,000. It is frequently the case that the cars at this transfer point include several loaded with dynamite from a factory only 8 miles away and it was only good fortune that prevented their presence on this occasion. Under the present Federal law the shipper who offers to a railway a dangerous article, such as gasolene, or rubber cement, without marking the packages correctly and, in addition, giving to the carrier infor-

mation as to the characteristics of the material shipped, is liable to incur the heavy penalty of 18 months' imprisonment and a fine of $2000. The labels, prescribed by the railway and illustrated above, have been designed to facilitate compliance with this law. They must be furnished and attached to his packages by the shipper.

The shipper must also describe his material correctly on his shipping order and write, stamp or print thereon, immediately

FIG. 20.

above his signature, or that of his authorized agent, the following certificate:

> This is to certify that the articles in this shipment are properly described, packed and marked, and that all necessary labels have been attached to packages, as required by paragraphs 1801 to 1857, inclusive, of the Regulations for the Transportation of Inflammable Articles and Acids.

A shipper who signs this certificate must be familiar (1) with the regulations, and (2) with the characteristics of his shipments. Without this familiarity his certificate is liable to

give false and misleading information to the carrier in violation of the law.

Opposite each entry of material requiring a label must be stated the kind of label attached to the packages. The materials that require labels are determined by comparing their characteristics with standard definitions:

DEFINITIONS.

1801. **Inflammable Liquids.—Red Label.**—This group includes any material, compound, or mixture, that gives off inflammable vapors (as determined by flash point from Tagliabue's Open Cup Tester, as used for test of burning oils) at or below a temperature of 80° F. (For examples and quantities, see List No. 1, Paragraph 1805.)

1802. **Inflammables. — Yellow Label.** — This group includes: (1) Materials subject to spontaneous combustion; and (2) materials, other than acids, that are liable to *cause* fires by friction, by concussion, by absorption of moisture, by contact with organic matter, or otherwise. (For examples, see List No. 1, Paragraph 1805.)

1803. **Compressed Gases or Liquids.**—This group includes the following gases:

Inflammable Gases. Red Label. (Inflammable Placard on car.)	Acetylene Gas. Coal Gas. Ethyl Chloride. Hydrogen Gas. Pintsch Gas.
Non-Inflammable Gases. Light Green Label. (No Placard required on car.)	Anhydrous Ammonia. Carbonic Acid (Carbon Dioxide) Gas. Chlorine Gas. Compressed Air. Nitrous Oxide (Dental Gas). Oxygen Gas. Sulphur Dioxide.

NOTE.—Hydrogen and Oxygen Cylinders are shipped in pairs for Calcium Lights.

1804. **Acids.—White Label.** — This group includes the following substances:

Acid, Hydrochloric. (Muriatic Acid.)
Acid, Hydrofluoric. (Etching Acid.)
Acid, Nitrating. (Mixed Sulphuric and Nitric.)
Acid, Nitric. (Aqua Fortis.)
Acid, Sulphuric. (Oil of Vitriol.)
Bromine.
Phosphorus, Trichloride.
Sulphur, Chloride.

To assist in applying the definitions, lists of the principal inflammable articles are given. A list is also given of "Doubtful Articles," the doubt being due to the use of the same name to describe a variety of substances, some of them inflammable under the definitions:

PRINCIPAL INFLAMMABLE ARTICLES AND ACIDS.

1805. The following list (No. 1) shows the principal inflammable articles and acids covered by these regulations, and the quantities which may be shipped in one package without a label when certified "No Label Required." (See Pars. 1814 and 1815.)

LIST NO. 1.—INFLAMMABLE LIQUIDS.—RED LABEL.

NAME.	Flash Point. (May vary with purity.) Deg. F.	Maximum quantity (see Pars. 1814 and 1815) in one package which may be certified "No Label Required."
Acetone	35	½ gallon.
Alcohol, denatured	40–55	1 gallon.
Alcohol, grain (ethyl alcohol)	57	1 gallon.
Alcohol, wood (methyl alcohol)	45	1 gallon.
Amyl Acetate	70–95	1 gallon.
Benzene	20	½ gallon.
Benzine	*Zero	½ gallon.
Benzole	20	½ gallon.
Carbon Bisulphide	*Zero	No exemption.
Coal Tar Naphtha (light oil)	20	½ gallon.
Collodion	*40	½ gallon.
Cologne Spirits	60	5 gallons.
Columbian Spirits	45	1 gallon.
Ether	*Zero	5 pounds.
Ethyl Acetate	40	1 gallon.
Ethyl Chloride	*Zero	3 doz. 4½ oz. tubes.
Ethyl Methyl Ketone	30	½ gallon.
Ethyl Nitrite	*Zero	½ gallon.
Gasolene	*Zero	½ gallon.
High Wines (proof spirits over 100 proof)	60–80	1 gallon.
Hydro-Carbon (Pintsch gas drips)	*Zero	½ gallon.
Lacquer (Nitro-Cellulose solution)	20–70	½ gallon.
Lacquer (Shellac)	40–70	1 gallon.
Leather Cement	*Zero	½ gallon.
Liquid Bronze	*40	½ gallon.
Naphtha	*Zero	½ gallon.
Naphtha Cement	*Zero	½ gallon.
Nitro-Cellulose, solution	20–70	½ gallon.
Nitro-Cellulose, wet with solvent	40	5 pounds.
Neutral Spirits	57	1 gallon.
Nitro-Glycerin Spirits	†60	No exemption.
Paint (bronzing, aluminum and gold)	*20–70	½ gallon.
Petroleum Ether	*Zero	½ gallon.
Petroleum Naphtha	*Zero	½ gallon.
Petroleum Spirit	*Zero	½ gallon.
Proof Spirits	60–80	1 gallon.
Pyroxylene (see Nitro-Cellulose)		
Rhigolene	*Zero	½ gallon.
Rubber Cement	*Zero	½ gallon.
Rubber Solution	*Zero	½ gallon.
Shellac, liquid	40–70	1 gallon.
Soluble Cotton (see Nitro-Cellulose)		
Spirits Glonoin (Nitro-Glycerin Spirits)	†60	No exemption.
Toluene		
Toluol	55	1 gallon.
Wood Spirit	45	1 gallon.

*At or below. †Approximate.

INFLAMMABLES.—YELLOW LABEL.

NAME.	Maximum quantity (see Pars. 1814 and 1815) in one package which may be certified "No Label Required."
Bags, empty, used for Nitrate of Soda	No exemption.
Barium Peroxide	No exemption.
Calcium Phosphide	5 pounds.
Charcoal, ground	10 pounds.
Charcoal, lump	10 pounds.
Chlorates	25 pounds.
Chromic Acid (anhydrous)	10 pounds.
Collodion Cotton (see Nitro-Cellulose)	
Cotton Waste, oily‡	No exemption.
Desiccated Leather (fertilizer ingredient)	10 pounds.
Dried Fish or Fish Scrap (fertilizer ingredient)	10 pounds.
Fillerine (fertilizer ingredient)	10 pounds.
Garbage Tankage (fertilizer ingredient)	10 pounds.
Gas Purifying Waste (fertilizer ingredient)	10 pounds.
Gun-Cotton (see Nitro-Cellulose)	
Iron Mass, spent	10 pounds.
Iron Sponge, spent	10 pounds.
Magnesium Powder	5 pounds.
Matches, friction	No exemption.
Metallic Potassium	No exemption.
Metallic Sodium	No exemption.
Negative Cotton (see Nitro-Cellulose)	
Nitrate of Potash, in bags	No exemption.
Nitrate of Soda, in bags	No exemption.
Nitrates, in bags	No exemption.
Nitre, in bags	No exemption.
Nitro-Cellulose, dry (*see High Explosives*)	
Nitro-Cellulose, wet with water	No exemption.
Phosphorus, yellow	No exemption.
Potash, chlorate	25 pounds.
Potash, permanganate	25 pounds.
Potassium Peroxide	No exemption.
Pyroxylin (see Nitro-Cellulose)	
Saltpetre, in bags	No exemption.
Sodium Peroxide	No exemption.
Soluble Cotton (see Nitro-Cellulose)	
Soot	10 pounds.
Zinc Dust	10 pounds.
Zinc Flue Dust	10 pounds.

‡Cotton Waste, oily with linseed oil, must not be shipped.

NOTE.—Labels must be applied to at least 10 per cent. of bags containing Inflammables, in L. C. L. shipments.

ACIDS.—WHITE LABEL.

NAME.	Maximum quantity (see Pars. 1814 and 1815) in one package which may be certified "No Label Required."
Acid, Hydrochloric (Muriatic)	5 pints.
Acid, Hydrofluoric (etching acid)	5 pints.
Acid, Nitrating (mixed Sulphuric and Nitric)	No exemption.
Acid, Nitric	No exemption.
Acid, Sulphuric (Oil of Vitriol)	5 pints.
Bromine	No exemption.
Phosphorus Trichloride	5 pints.
Sulphur Chloride	5 pints.

LIST NO. 2.—DOUBTFUL ARTICLES.

Partial list of general names * of groups of articles that will require: (1) Shippers' Certificate, (2) Notation as to labels applied or not required and (3) Waybill endorsements, Par. 1873. (See Par. 1815.)

Automobile Supplies, N. O. S.
Blacking, N. O. S.
Blacking, stove, liquid.
Cement, liquid, N. O. S.
Cement, roofing.
Chemicals, N. O. S.
Compounds, polishing, N. O. S.
Compounds, type cleaning.
Compounds, vulcanizing.
Compounds, wall cleaning.
Compounds, waterproofing.
Crude Oil.
Dip, sheep.
Disinfectants, liquid, N. O. S.
Drier, paint and Japan, N. O. S.
Drugs, N. O. S.
Eradicator, paint or grease.
Extracts, N. O. S. (see List No. 3).
Gas Oil.
Laboratory Supplies, N. O. S.
Liniments.
Liquids, N. O. S.
Matches, N. O. S.
Nitrotoluol (may be Trinitroluol, a high explosive).
Oil, N. O. S.
Paints, N. O. S.
Paste, shoe.
Petroleum products, N. O. S. (See List No. 3.)
Pitch Roof Coating.
Polish, floor, liquid.
Polish, furniture.
Polish, liquid, N. O. S.
Polish, metal.
Polish, stove, liquid.
Preparations, insect and vermin destroying.
Preservers, iron, steel or wood.
Removers, paints, oil or varnish.
Shellac, liquid, N. O. S.
Softeners, leather.
Solvents.
Stain, furniture.
Stain, leather.
Strontia.
Turpentine Substitutes.
Varnish, N. O. S.
Varnish and Paint Removers.

* NOTE.—When practicable to avoid it, safe articles should not be described by genera names that suggest doubtful characteristics.

When an article, not covered by the definitions, is shipped under one of these doubtful names, the shipper must state on his shipping order, "No Label Required" and furnish the shipper's certificate.

The regulations contain also a long list of "Excepted

Articles," articles that have been investigated by the Bureau and found, from their characteristics, or the method used in packing them, to be safe for transportation without certificates or labels. This list is revised twice a year.

All of the regulations for inflammable articles, so far as they relate to the duties of shippers, are published as an appendix to the "Official Classification" and filed with the Interstate Commerce Commission. This removes any doubt as to their legal status and prevents also any possibility of conflict with the provisions of the Official Classification. For example, this book gives a classification for "Petroleum Products" in jacketed cans,

FIG. 21.

Proposed dynamite gun.

and the inflammable regulations prohibit the shipment of any liquid with a flash point below 80° F. in such a can unless the can is protected by a strong crate or box. Wherever applicable, the regulations must be the shipper's guide (Official Classification, Rule 35).

CONCLUSION.

The organization and work of the Bureau of Explosives represents an important step in the Federal control of interstate transportation of dangerous articles. The regulations for explosives, resulting from experience and the joint action of transportation and manufacturing interests, have now the support of Federal adoption. The Federal agent, the Interstate Commerce

FIG. 22.

NOTICE TO
RAILWAY EMPLOYES
CAUTION
Keep Away from FIRE, STOVES, RADIATORS, Lighted MATCHES, LANTERNS, and Direct Sunlight.
Any LEAKING Packages Must be Removed to a Safe Place.
Shipper has certified on his Shipping Order to compliance with all Regulations that apply to this package.

FIG. 23.

NOTICE
HANDLE CAREFULLY
ACID
DO NOT LOAD WITH EXPLOSIVES OR INFLAMMABLES PROTECTED BY YELLOW LABELS
Shipper has certified on his Shipping Order to compliance with all Regulations that apply to this package.

FIG. 24.

CAUTION TO
RAILWAY EMPLOYES
Compressed
NON-INFLAMMABLE
Keep Cool and Do Not Drop
Shipper has certified on his Shipping Order to compliance with all Regulations that apply to this package.

FIG. 25.

NOTICE TO
RAILWAY EMPLOYES
CAUTION
KEEP FIRE AND LIGHTS AWAY
Sweep Up and Remove Carefully Contents of Broken Packages
Shipper has Certified on his Shipping Order to compliance with all Regulations that apply to this package

FIG. 26.

CAUTION TO
RAILWAY EMPLOYES
Compressed
INFLAMMABLE
Keep Cool and Do Not Drop
Shipper has certified on his Shipping Order to compliance with all Regulations that apply to this package.

FIG. 27.

Various kinds of inflammable placards.

Commission, while vested with plenary power to over-rule them, is working in complete harmony with these interests. The Bureau is agent of both interests, the manufacturers being admitted to associate membership. The confidence of the Interstate Commerce Commission in it is shown by the following paragraph from the Commission's regulations, to which the underscoring has been added:

> 1531. Forbidden explosives, as defined in paragraph 1501, *and explosives condemned by the Bureau of Explosives,* must not be accepted for shipment.

In the development of the Bureau, and in its active work up to the present time, President Taft has shown his interest and approval by allowing, at request of the American Railway Association, an officer of the ordnance department of the army, with experience in the manufacture, use and handling of explosives, to co-operate with railway officials. It seems to be the desire of these officials to continue this co-operation as long as possible, and this work offers greater opportunities than regular military duties for useful service to the public. The actual authority exercised by the officer comes entirely from transportation sources.

The regulations for inflammables have been developed by the same general methods and the time has now arrived for the Federal Congress to amend Section 233 of the Penal Code by extending the authority of the Interstate Commerce Commission to cover "other dangerous articles" as well as explosives. The moral effect of this would be of great assistance to the Bureau in securing a more strict compliance with the rules by shippers and railway employees.

The writer will be pleased to receive from any reader of this article suggestions for improving the policy or work of the Bureau. All who approve the object and methods of the Bureau are requested to utilize convenient opportunities to express this approval and especially to those shippers of dangerous articles who, through misapprehension of our objects, or through a selfish desire to economize the cost of their packing at the expense of safety, are inclined to resist enforcement of the rules.

FRANKLIN INSTITUTE

(Stated meeting, held Wednesday, February 16, 1910.)

DEVELOPMENT OF THE MALLET LOCOMOTIVE.

BY

MR. GRAFTON GREENOUGH,

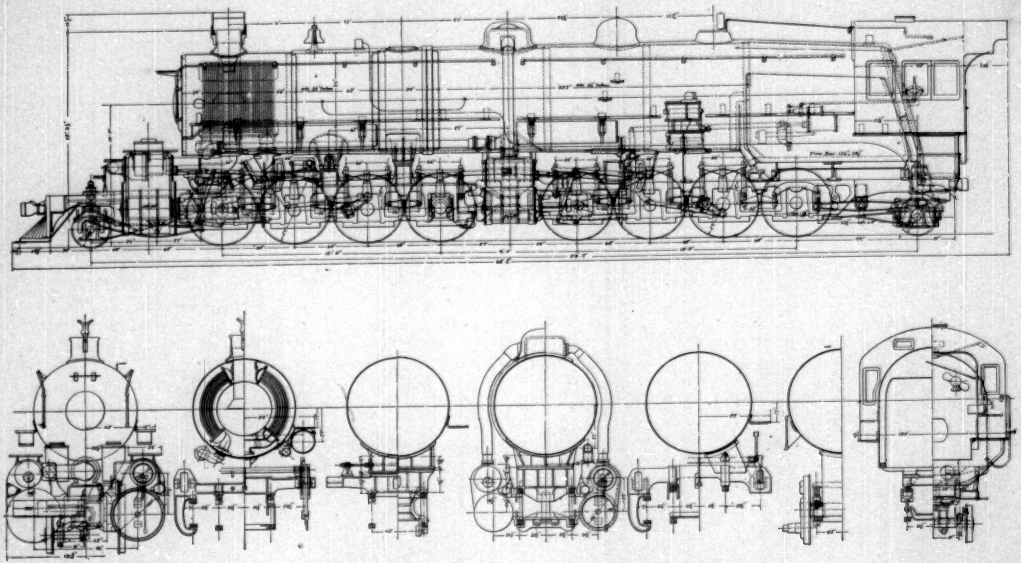
Manager Sales Department, Baldwin Locomotive Works.

[The Mallet Articulated Locomotive differs from the common types of rigid frame locomotives, in that it comprises a combination of two separate engines, one being high pressure and one low pressure, with one boiler.

It differs from other flexible locomotives because the high-pressure engine is secured to the firebox end of the boiler whilst the low-pressure engine supports the smokebox end of the boiler and is hinged to the front end of the high-pressure engine.

This design of locomotive has proven well adapted to the peculiarities of American Railroads, and it is with the progress of this adaptation we are particularly interested.]

NEARLY two years ago it was my privilege to address the Engineers Club of this city with regard to the introduction of Mallet locomotives in the railroad service of this country. Since that time the adoption of the Mallet Articulated locomotive in not only a limited field of service, but in widely diversified fields, has resulted in developments of design which I hope will prove of sufficient interest to command your kind attention. In order to avoid starting our discussion half way up the ladder of progress, with your permission, I will refer briefly to some of the fundamental principles of Mallet construction which form the foundation upon which all successful developments of the articulated locomotives are based. In the practical walks of life all progress, like the mountain stream choosing its path to the sea, follows the lines of least resistance, hence we find in what might be termed "commercially applied mechanics" a series of compromises bearing perhaps first one way, and then another. The history of railroad development in this country has proven no exception to this rule, as in order to meet the ever increasing demand for an increase in transportation facilities, the growth of the locomotive and the improvement of the roadway, which includes roadbed, track,



First Consolidation Mallet locomotive, Southern Pacific Railway.

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COLLEGE
LIBRARY.

trestles, and bridges over which the locomotives must operate, show alternate advances in those divisions of railroad property, which have usually been made with a view to causing the least possible change in other divisions. To use existing roadways in the early days of railroading, the number of wheels carrying a locomotive was increased, only to be again reduced in order to simplify the locomotive, as in turn better roadways were provided to carry an increased weight per wheel. This process of development through intermittent stages brought what we are pleased to term the common types of locomotives, or perhaps more distinctively rigid frame locomotives, to a high degree of practical efficiency. Until Mallet locomotives were used it was thought that 125 tons in working order was practically the limit of weight on the drivers which could be utilized in one locomotive. Even such engines could only be used in comparatively few places because of their long rigid wheel-bases and their limited ability to curve freely. A few engines approaching this weight had been built, of the Consolidation Type, but they could only be used on rails approximating 90 pounds weight per yard—and comparatively small mileage was laid with such rails. Some engines approximating this weight were built with five pairs of driving-wheels, either of the Decapod Type with a leading truck only, or of the Santa Fe Type with five pairs of driving-wheels, and a two-wheeled truck front and back. The several additional feet of rigid wheel-base in the last two named types, however, proved a very serious obstacle and precluded a universal acceptance of those designs. Consequently, Railroad Companies had almost concluded that the solution to their problem of moving greater train loads must lay in either widening the gauge of their roads and providing stronger and heavier locomotives of existing designs, or in increasing the number of locomotives per train. The latter expedient was adopted to such an extent that on many heavy grade divisions it was not uncommon for three locomotives to be attached to a single train. Evidently such an expedient could only afford temporary relief, yet the enormous outlay required to increase the gauge of our many thousand miles of railroad banished hope of relief in that direction. The path of least resistance surely seemed to lead to a change in the design of locomotives whereby their power and size might be increased

Although their maximum height and width had been reached, because of the limiting gauge, growth was still possible through an increase in length.

In this dilemma attention was turned to the Mallet design, which had been used to some extent abroad, although no engines of that type had been built which even approximated the weight or size of rigid frame engines in use on our American Railroads.

The feasability of adapting the Mallet principle to our conditions was long considered before any could be found with sufficient temerity to make a definite trial. The first road to make this trial was the Baltimore & Ohio Railroad Company, which had one Mallet Articulated locomotive built by the American Locomotive Company in 1904 for pusher service on Sand Patch Hill, near Connellsville, Pennsylvania. This engine is still doing efficient work. The trial, however, which bids fair to revolutionize railroading, was made shortly after, when the Great Northern Railway placed in service five Mallet engines built by the Baldwin Locomotive Works.

The designs of these first Mallets for the Baltimore and Ohio Railroad and the Great Northern Railway embodied all those peculiar features which distinguish the Mallet locomotive from other flexible or articulated engines. In common they had three pairs of driving-wheels in each group, the rear group being held in a rigid frame to which the high-pressure cylinders and boiler were attached. The forward group was held in a frame to which was fastened the low-pressure cylinders, and also transverse brackets which supported the forward end of the boiler. Each group of wheels was operated by an independent pair of cylinders, pistons, crossheads, connecting rods, valve motion, and consequently each combination comprised an independent engine; the forward engine being attached to the rear engine by a kingpin located about half way between their adjacent driving-wheels, so that the forward engine would articulate about the kingpin at its rear just as the forearm of a human being articulates about the elbow-joint.

This arrangement, it is found, gives just the range in curving ability which is requisite under conditions common to American Railroad practice—to increase the driving-wheel base of locomotives without increasing the strength of roadway or without changing curves. In other words, if a roadway is suitable for

Consolidation engines of a given rigid wheel-base and a given weight per wheel, it is also suitable for what we have begun to term Consolidation Mallets with sixteen driving-wheels and a two-wheeled truck front and back, which is virtually the equivalent of two consolidation locomotives hinged back to back.

Aside from some minor details of construction there was also a fundamental difference in the designs of the locomotives for the two roads. The Baltimore & Ohio locomotive had no truck-wheels, whilst the Great Northern engine had both a leading and a trailing two-wheeled truck, thus exemplifying an important variance in opinion existing between the two builders.

The American Locomotive Company has strongly espoused the cause of "No trucks" for Mallet locomotives for reasons which are ably set forth by their Consulting Engineer, Mr. C. J. Mellin, in his paper of December, 1908, before the American Society of Mechanical Engineers, alleging that trucks involve objectionable first cost, maintenance charges, dead weight, unfavorable distribution of weight and produce the same result as putting a "truck in front of a truck" because the first engine of a Mallet locomotive is practically a truck. He furthermore charges the use of the front truck with increasing the distance from the front drivers to the front bumper, increasing the wheel-base of the locomotive and where a rear truck is not used also with necessitating the boiler being moved forward, so that the width of the firebox is limited to approximately 72 inches in order to clear the valve motion. On the other hand, the Baldwin Locomotive Works have always advocated the use of trucks for Mallet locomotives under all conditions which render trucks advisable in rigid frame locomotives, hence it will be interesting to follow the ultimate outcome of this difference in opinion.

Let us for a moment consider the use of trucks on common types of rigid frame locomotives. Front trucks are provided for Mogul locomotives, for Consolidation locomotives, and for Decapod locomotives, to steady the front end of the locomotive, to assist in guiding the engines around curves and to reduce the wear of flanges on the driving-wheels.

The ability of properly designed trucks to perform these functions has been proven by actual practice and universally acknowledged for all service other than switching at slow speed.

Numerous trials with a view to dispensing with trucks by using six- and eight-coupled engines without trucks have resulted in failure, and hardy indeed would be the man who attempted to use such engines in freight or passenger road service, notwithstanding the fact that trucks cost money and have to be maintained, and although they also add dead weight and lengthen wheel-bases and increase the distance from the centre of drivers to the front bumper, just as is correctly charged. But trucks perform necessary functions which cannot be dispensed with and because they do so Railroad Companies accept the minor disadvantages to avoid the greater costs likely to result from damaged track and tires, and the expense of damages due to derailments. When locomotives with the same number of driving-wheels as Moguls, Consolidations and Decapods are required for service which requires frequent or continuous backing, it is quite common to apply rear trucks in addition, thus making the engines what are commonly known as "Double-end ten-wheelers," "Mikadoes" and "Santa Fe Type" locomotives; and these back trucks prove their worth in spite of the same objections.

It is frequently desirable to place the firebox of a locomotive back of, or partially back of the rear driving-wheels, because of the length of boiler needed to provide sufficient heating surface or because of the size of drivers and the necessity of obtaining a deep firebox, thus causing considerable overhanging weight at the back end. In such cases rear truck wheels or radial trailing wheels are introduced to support the overhanging firebox. As instances we have the Atlantic and Pacific Type locomotives.

A little reflection will show that a Mallet locomotive can always be likened to two rigid type locomotives placed back to back insofar as wheel arrangement is concerned, consequently if any of the conditions above recited apply to one of the component engines, whereby it would be advantageous for that engine to have trucks, it is also in order for the Mallet locomotive to have trucks, so that the Mallet locomotive may be enabled to perform the same service equally well and at the same speed.

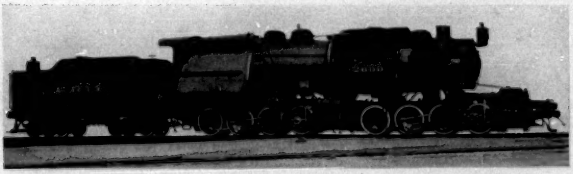
It is argued that each group of Mallet drivers may be considered a "truck." This is perfectly true as regards the first group of drivers leading the second group into a curve,

but it is misleading as applied to the entering group while taking the curve, because the first group has the same rigid wheel-base and the same weight per wheel as the Mogul and Consolidation locomotives which have trucks, and so need the same assistance in curving for precisely the same reasons.

Subsequent experience has shown that proper distribution of weight can be obtained by correctly locating boiler and boiler bearings whether with or without trucks, and as locomotives have been built for road service with forward truck only and a firebox 96 inches wide, we know that the valve motion has not been interfered with by the firebox of such engines.

Hence, notwithstanding the increased cost, trucks are just as essential to the front group of driving-wheels of a Mallet locomotive when curving forward, to the back group when

FIG. 1.



Mallet locomotive, Erie R. R. Built by American Locomotive Co.

curving backward, or to carrying an overhanging firebox, as they are in performing similar service for individual locomotives which are similar to those which form a group or unit in a Mallet engine (Fig. 1).

The Mallet locomotives with six pairs of driving-wheels were hardly in service, and the novelty of their design had not worn off, before something heavier was demanded. The American Locomotive Company then built for the Susquehanna Division of the Erie Railroad several Mallet pushing engines with eight pairs of driving-wheels without trucks. These locomotives were of the conventional type, weighed in working order 410,000 pounds, and were when built the heaviest engines in the world, but subsequent events have wrested from them that distinction.

The engines which mark an epoch in Mallet construction and make the use of the largest articulated engines possible,

with a minimum change in repair-shop methods are the two built by the Baldwin Locomotive Works for the Southern Pacific Railway in 1909 (see illustration facing page 202).

These locomotives had eight pairs of driving-wheels in two groups, with a two-wheeled truck front and back, and weigh 425,900 pounds in working order with 394,150 pounds on the drivers. Heretofore Mallet locomotives had been constructed with the common type of boiler with extra long flues, whereas the boilers of these engines are composed of a steam generator or boiler proper, with tubes of normal length; forward of the front tube-sheet is a combustion chamber. In front of the combustion chamber is a feed water-heater, with at least as many firetubes passing through it as are in the generator, and ahead of all is the smokebox. The feed water-heater is kept full of water at all times; cold water is forced into it by the injectors, which in turn displaces and forces the water from the heater into the generator at a temperature much above the boiling point. The major portion of scale is deposited in the heater, and the generator is relieved of scale troubles and also of the strains and their consequences due to forcing cold water directly into a boiler.

This arrangement of boiler also made it possible to effect another vital improvement, which is, the division of the engine into two parts by dividing the boiler at the combustion chamber and the holding of these two parts together by bolts, joining two self-centring rings fastened to the combustion chamber. As the Mallet feature divides the machinery in two it was but one more step to divide the boiler also. The "units" by means of the bolts in the connecting rings, the kingbolt, and a few pipe joints can be either separated or joined together in several hours, and when separated, the individual halves or units can be handled in a repair shop with the same facilities required by the common sizes of locomotives. The importance of this can only be appreciated by those having to do with the upkeep of motive power. Among the minor improvements embodied in these engines is the use of a single instead of a double joint between the two engines. The sand-boxes are placed on the bumper-plate of the forward engine so that no flexible sand pipes are necessary and instead of using sight feed lubricators to oil the low-pressure cylinders, precision

force-pumps are applied, thus eliminating flexible pipes for that purpose also. A superheater is installed in the smokebox for reheating the steam passing from the high- to the low-pressure cylinders and a Ragonnet power reverse was applied to relieve the engine men of unnecessary physical strain due to handling an engine of this size. The results obtained from these engines have been excellent, both as regards efficiency and economy. Oil is used for fuel and the engines have shown themselves capable of developing in service a horse-power per hour for the equivalent of 1¾ pounds of coal.

Service tests by the Railroad Company comparing these engines with common standard Single Expansion Consolidations on the same division, as reported in the *Railway Age Gazette* January 14, 1910, show relative gains in favor of the Mallets as follows:

Equivalent evaporation per pound of fuel	7.81 per cent.
Ton-miles per gallon of water used for main cylinders	14.04 per cent.
Ton-miles per pound of oil burned	22.50 per cent.
Tonnage hauled	119.54 per cent.

Although the Mallet engine only weighed 104 per cent. more than the Consolidation, it hauled a train weighing 119 per cent. more, thus showing its ability to provide sufficient steam to maintain a higher efficiency.

An evidence of the Railroad Company's appreciation of the work done by these engines is obtained from the fact that an order for 21 duplicates is now being filled.

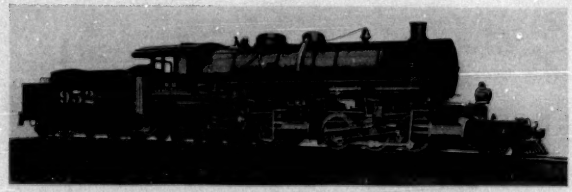
For a time the interest in Mallet engines centred largely in the Northwest; Mr. James J. Hill felt sure he had found the type of locomotive for his needs and through his foresight the number of these engines was increased on the Roads dominated by his influence. With the return of prosperity the interest spread, aroused by accounts of pioneer accomplishments, and began to take a definite shape in all parts of the country. Mr. A. Robertson, General Manager of the Western Maryland R. R., placed two Mallets of the 2-6-6-2 type (Fig. 2), weighing 342,000 pounds with about 300,000 pounds on driving-wheels, in service near Hagerstown, Maryland. Each of these locomotives replaced two Consolidations as pushers and effected a saving per ton-mile of from 30 to 37½ per cent. in fuel and water.

Furthermore, they have the distinction of being the first Mallet locomotives in the East, having front and rear trucks, and as a result of their efficient service additional duplicate engines will shortly be added to the Company's equipment.

The next engines to mark a stage in the development of the Mallet locomotives are those recently shipped by the Baldwin Locomotive Works to the Atchison, Topeka & Santa Fe Railroad, one type, 2-8-8-2, for freight service, and a 4-4-6-2 for passenger service. Not only are these the largest locomotives ever built, but the passenger engine is the first of the Mallet type built distinctively for passenger service in this country (Fig. 3). To the courage of the convictions of Mr. J. W. Kendrick, Vice-President of the road, is this innovation due.

The freight engine weighs 462,000 pounds with 412,000

FIG. 2.



Mogul Mallet locomotive, Western Maryland R. R.

pounds on drivers 63 inches in diameter, and the passenger engine weighs 376,000 pounds with 268,000 pounds on drivers 73 inches in diameter. Both of these engines embody in their construction nearly all the features inaugurated by the Southern Pacific Mallets, and in addition the steam and receiver pipes are nearly all encased in the boiler, thus avoiding considerable condensation.

The Jacobs-Shubert superheater is placed in the combustion chamber to heat the high-pressure steam before it enters the high-pressure cylinders, and also to reheat the steam which exhausts from the high-pressure to the low-pressure cylinders.

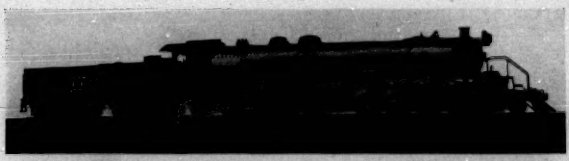
Incidentally it may be of interest to know these engines are equipped with Jacobs-Shubert fireboxes which eliminate the use of radial stays and side water-space stays. This has no connection other than an incidental one with the Mallet design,

as the type of firebox is applicable to the common types of locomotives.

Some locomotives designed distinctively for road service have been built with three pairs of driving-wheels and a two-wheeled truck in the front group and four pairs of drivers without rear truck in the rear group.

The first of these built for the Alabama Great Southern Railroad by the Baldwin Locomotive Works is planned on established lines with the exception that a smokebox reheater is provided. This engine, which weighs 363,000 pounds with 332,000 pounds on driving-wheels, is designed to haul 1650 tons of cars and lading up a 1¼ per cent. grade in conjunction

FIG. 3.



Consolidation Mallet locomotive, Atchison, Topeka & Santa Fe Ry. Heaviest locomotive in the world.

with 6-degree curves and has more than met expectations (see Fig. 4). Some of the same type locomotives are being shipped to the Great Northern Railway, which are equipped with Emerson superheaters designed to heat the high-pressure steam. It should be borne in mind that engines with this distribution of wheels are designed to do the bulk of their work running forward and for use where sufficient boiler capacity can be obtained without lengthening the boiler so that rear truck-wheels will be required to support it.

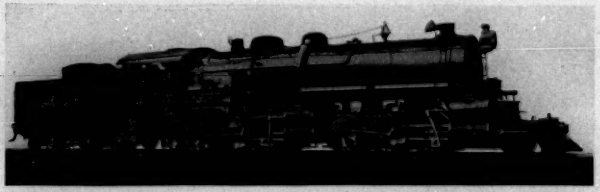
Some engines very similar in general design, except with trailing trucks instead of the rear driving-wheels, are being built for the Chicago, Burlington & Quincy Railroad (Fig. 5).

Experience with Mallet locomotives has dissipated a number of fallacies of a minor nature regarding certain details. It was first thought necessary to provide a double hinge at the centre of articulation, and also bolts to steady the rear end of the front engine by flexibly joining them to the front end of the rear frame (Fig. 6).

A simpler connection can frequently be used and the frames of the two engines be made to dove-tail so the front frame is held in position vertically, but permitted to swing horizontally, thus all twisting strains in the hinge are eliminated. This simple connection can usually be employed except when it is not possible or convenient to locate the centre of the joint at the normal centre of articulation, in which contingency it is necessary to provide some lateral flexibility which is usually obtained by means of springs.

It has also been found that some of the ball-joints of the flexible exhaust and receiver pipes, could be held more uniformly through the introduction of a spring and this detail has been accordingly improved (Fig. 7).

FIG. 4.

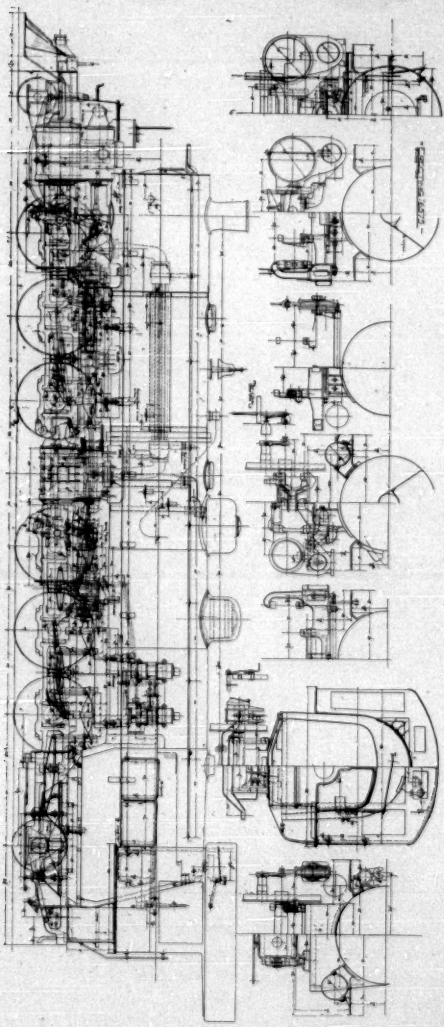


Mallet locomotive, for Alabama Great Southern R. R.

From the first the Baldwin Locomotive Works contended that no intercepting valve was necessary to supply high-pressure steam to the low-pressure cylinders. Actual practice has vindicated this stand as an inch or an inch-and-a-quarter pipe, controlled by a globe-valve, and leading to the receiver-pipe, supplies all steam necessary for starting or drifting.

A simple reverse gear adapted to locomotive practice by Mr. Ragonnet has been used to advantage. It can be operated by either steam or air and will adjust itself to automatically remain in unison with the controlling lever. No means of reversing by hand is provided on large Mallets built by the Baldwin Locomotive Works, whereas the power reverse in conjunction with a hand lever is provided by other builders.

The disadvantages of this latter method, namely, crowding the cab with a long moving lever, and the risk of injuring some-



Mogul Mallet locomotive, Chicago, Burlington & Quincy R. R.

FIG. 5.

one through an unexpected movement of the lever by power, more than overbalances the possibility of working the engine by hand if the power gear should fail.

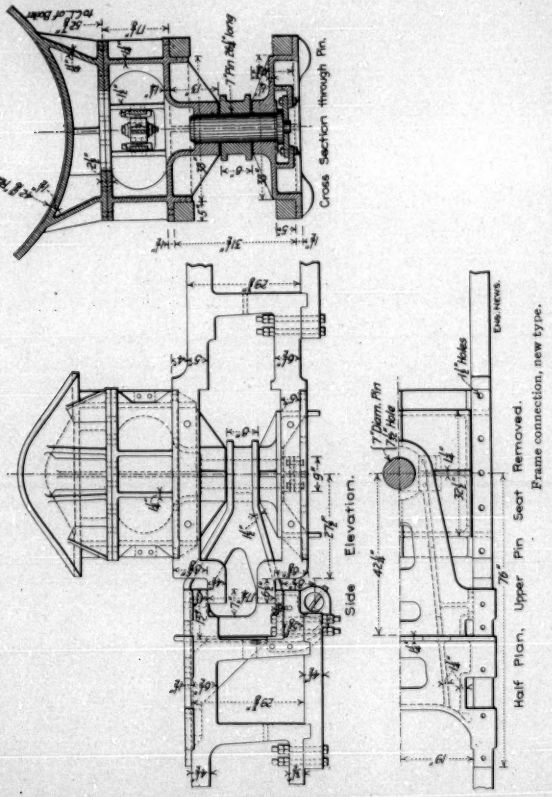


FIG. 6.

One important appliance, the superheater, has been incidentally spoken of. We know that superheaters are effective in single expansion engines and we know that Mallet locomotives without superheaters are efficient. We believe that the intelligent applica-

tion of superheaters will increase the efficiency of the Mallet engine and the talents of many are turned toward the proper solution of the problems presented. The advocates of super-

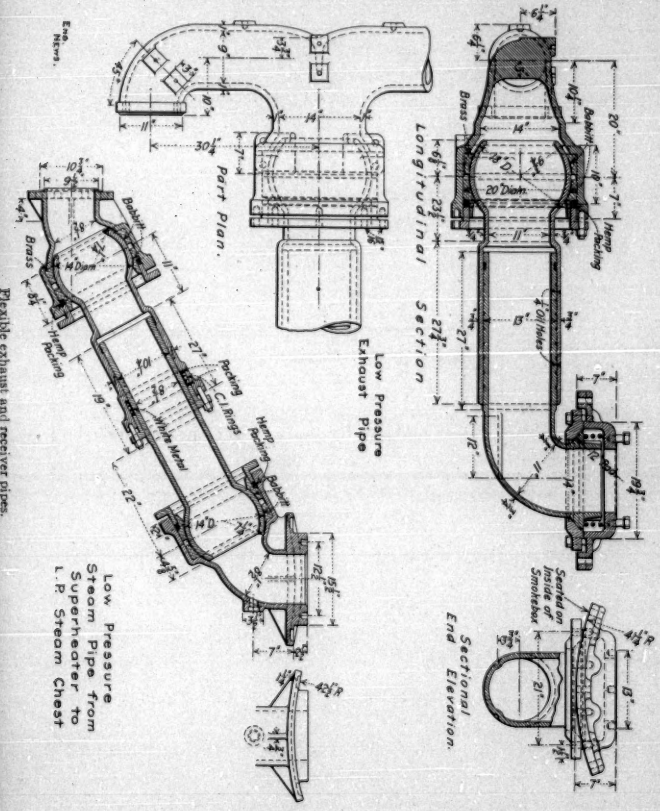

Part Plan.
Low Pressure Exhaust Pipe
Longitudinal Section
Low Pressure Steam Pipe from Superheater to L. P. Steam Chest
Sectional End Elevation.
Flexible exhaust and receiver pipes.

FIG. 7.

heaters may be divided into two classes, viz., those who urge a high degree of superheat and those who prefer to only superheat sufficiently to ensure the steam remaining dry throughout the stroke.

The only superheater of the former type used on Mallet engines is the "Emerson" which is an extremely simple application of the Schmitz design of firetube superheater. This superheater is installed in tubes extending through the waist of the boiler and necessarily makes some change in boiler construction. The superheater tubes, however, are so arranged that each unit can be removed without disturbing either of the main steam pipes to which they are attached. It will further be noted that the path of the tubes is at all times common to the path of exhaust gases and cinders. Hence there are no joints to be cut out or destroyed by the action of the draft.

The Jacobs-Shubert superheater is composed of one or two steam-drums with firetubes passing through them. This type of superheater is installed in the smokebox of ordinary type locomotives, or in the combustion chamber of smokebox of Mallet engines. It is of the low-superheat type and has proven very efficient.

The Vauclain Type of superheater is another design of low-temperature apparatus; it is composed of steamtubes heated by external gases, and enjoys the distinction of being the simplest superheater yet devised. It practically takes the place of the smokebox steam-pipes and can be applied either in the smokebox or the combustion chamber of a Mallet engine without changing boiler design, and in spite of its simplicity has proven very effective in practice.

The question regarding the use of superheated steam in Mallet locomotives relates not only to the type of superheater, but also to the location of the superheater, and to the stage in which the steam is to be superheated.

In the single expansion engine the superheater can only be placed in the smokebox or in the firetubes of the boiler, whereas in the Mallet engine the superheater may also be placed in an internal combustion chamber; and furthermore in a Mallet locomotive the steam may be either superheated before entering the high-pressure cylinders or reheated after leaving it, in which event the superheater is more properly called a reheater.

Mallet engines have been built or are building which individually embody these different methods of superheating steam, but experience in the use of such engines has not extended over sufficient time to definitely state whether or not it is advantageous to superheat steam before it enters the high-pressure cylinders,

although it is generally admitted, even by those who have little sympathy with the use of superheated steam in the common types of locomotives, that a reheater between the high- and low-pressure cylinders is advantageous. This reheater is in some instances a modification of the Vauclain superheater, it being a group of steam-tubes passing through a longitudinal cylindrical passage in the feed water-heater. These tubes are rolled in headers which in turn form part of the receiver pipe. Another arrangement whereby firetubes comprise a portion of the receiver pipe, while passing through the feed water-heater, is designed but has not yet been tried.

In some instances the use of Mallet locomotives bids fair to retire from service some of the older types of freight engines which are still in good working condition. As a remedy for this contingency it was proposed to use the discarded locomotive as the back end of a Mallet engine, and add to it a front end or unit. This idea, first suggested by Mr. George H. Emerson of the Great Northern Railway, has been worked out by the Baldwin Locomotive Works, and the first unit has been built and applied to the old engine by the Railroad Company and is reported as showing excellent results during its preliminary trials. It will be seen that the development of this idea presents the means of increasing the efficiency of the common type locomotives from 60 to 75 per cent.

In the instance under consideration the engine rebuilt was a Consolidation, and the old boiler, firebox, cylinders, wheels and frames were used as the high-pressure engine. The boiler was extended by attaching a water-heater and smokebox to the old smokebox, which in turn became the combustion chamber. The water-heater and new smokebox were supported by a new frame with three pairs of driving-wheels, the original tender truck, pilot and bumper were transferred to the forward end of the new unit and alterations made in the front end of the old engine frames to allow the hinge arrangement connecting the two engines to be applied. Similar units are being built for the Chicago & Great Western and the Erie Railroad Companies.

All of the foregoing deals with accomplishments of the past, and we may now turn our attention for a few moments to the ideas which are in process of development and bid fair to become actualities.

Just as when the earliest and smallest four-wheeled engines

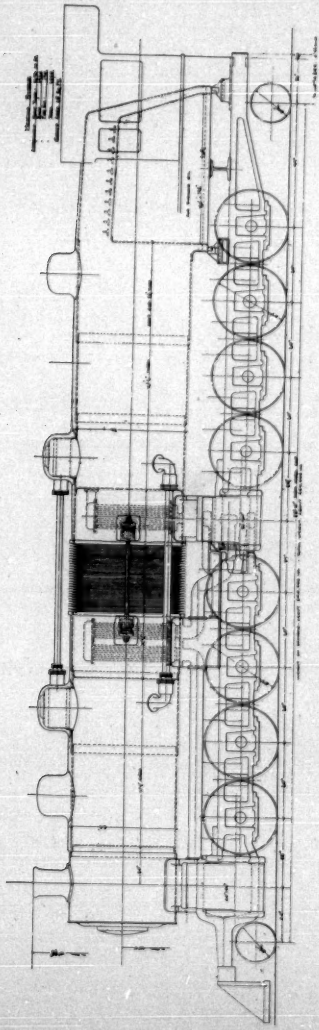
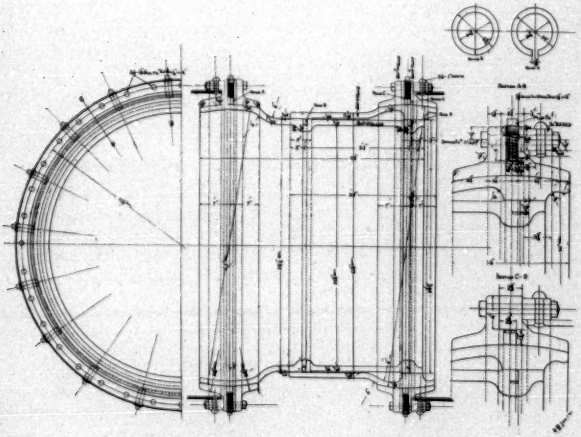


FIG. 8.

Consolidation Mallet locomotive with flexible boiler—bellows type.

were hardly in active service before endeavors were afoot to increase their size and capacity so also was the popularity of the Mallet locomotive barely established when our attention was likewise turned to the possibility of providing motive power still larger and more effective. With this thought in view it is now proposed to articulate the boiler at the combustion chamber, thus avoiding the lateral overhang of the front end of the boiler on curves, and permitting the use of a larger boiler without

FIG. 9.



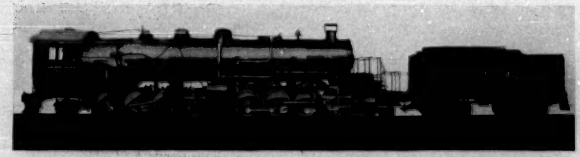
Detail of ball-joint boiler connection.

affecting the stability of the engine. Two methods by which this can be accomplished have been devised by Mr. S. M. Vauclain, and without doubt a trial locomotive embodying one or the other of these designs will soon be constructed. The first and simplest method is by means of what might be termed a bellows-joint, consisting of a number of thin sheet-rings riveted and bolted together. At first glance this design seems rather radical, but when it is remembered that owing to the large number of rings employed a 16-degree curve can be traversed with an average deflection of each ring amounting to perhaps 1/32 of an inch, the scheme assumes reasonable shape (Fig. 8). The

principal care of this device would arise from the necessity of keeping it clean internally.

The alternate method by which this flexible connection can be obtained embodies the use of a double ball-joint (Fig. 9). This latter plan allows greater freedom and motion to the boiler, and as there should be no difficulty experienced in keeping the joints properly lubricated the device is entirely feasible. The use of either of these designs also permits of the use of articulated engines on sharper curves than those of early Mallet design, and enables the rigid wheel-bases to be lengthened either because of larger driving-wheels or an increased number of driving-wheels. The common types of Mallet engines, because of the curves to be negotiated, are practically limited to four pairs of driving-

FIG. 10.



Latest type of consolidation Mallet locomotive, Southern Pacific Co.

wheels in a set, whereas with the articulated boiler engine five pairs can be easily arranged for.

The spread of Mallet Type popularity bids fair to overrun the entire country and has even entered both Mexico and Canada, as is shown by the following list of roads either using or having on order Mallet locomotives:

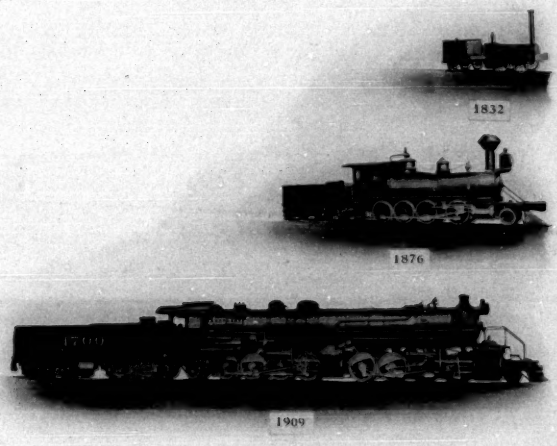
Baltimore & Ohio; Denver, Northwestern & Pacific; Delaware & Hudson; Boston & Albany; Denver & Rio Grande—from the American Locomotive Company. Great Northern; Northern Pacific; Chicago, Burlington & Quincy; Mexican Central; Associated Harriman Lines; Chicago Great Western; Western Maryland; Carolina, Clinchfield & Ohio; Atchison, Topeka & Santa Fe; Alabama Great Southern; Duluth, Missabe & Northern; Caspar Lumber Co.; Booth-Kelley Lumber Co.; Eastman, Gardiner & Co.; Little River Lumber Co.; and The Whitney Company—from the Baldwin Locomotive Works.

The Virginian and Norfolk & Western Railroads are having Mallets built by both Companies, so they may test the relative values of each builder's work.

The Canadian Pacific Railway has one engine built by their shops under the supervision of their Vice-President, Mr. H. H. Vaughan.

With perhaps a total of 125 Mallet engines actually at work in different parts of the country, and at least that number now building, we will doubtless witness, on account of the interest they command, a number of experimental developments from time to time. Contrary to our preconceived notions of what is regular, some Mallet locomotives have been built with the cabs

FIG. 11.



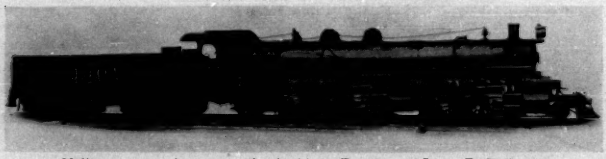
Relative sizes of locomotives: 1832, 1876, and 1909.

in front so that the engineer has an unobstructed view of the track and signals, and the tender is placed at the smoke stack end, which is also the back end of the engine. This arrangement is only practicable when oil fuel is used, but its advantages have already attracted considerable attention, and the attractive features of the design in one instance at least bids fair to be the means of changing the fuel used by the Company interested.

We have in a general way reviewed to date the development of Mallet engines on our American Railways, and whilst some details have been changed and improved, even the first Mallet

locomotives built and in service have proven more efficient than the types of engines they replaced. We find that wherever continuous heavy road-service, or heavy pushing-service is required, the Mallet Compound Articulated locomotive has more than done what was expected of it. We also find it, because of the articulated features, adapted to lighter work where rigid wheel-base engines are not practicable. In all heavy service of a nature which enables an engine to work a considerable portion of its time to anything like maximum efficiency, we find that in addition to being more effective than other types of engines, the Mallet locomotive is by far the most economical design of locomotive yet devised (Fig. 10). Without doubt its advent has eliminated the necessity for a time at least of widening the gauge of our railroads, and has in many instances postponed the laying of additional tracks because of the reduction in the number of train movements it makes possible. The progress of locomotive building is shown by Fig. 11.

FIG. 12.



Mallet passenger locomotive for Atchison, Topeka and Santa Fe Railroad.

Furthermore the introduction of the Mallet Type of locomotive has justified the retention of steam locomotives as motive power on economical grounds alone where in a number of instances electricity generated by water power bid fair to invade. That the solution for a time at least of the apparently insurmountable difficulties attending the hauling of heavier trains has been obtained with practically no change in roadways, is due primarily to the common-sense design of locomotive developed by Mr. Anatole Mallet, seconded by the untiring energy and perseverance of the railroad officials, who in conjunction with the builders of locomotives, had the temerity to give these engines a fair trial, and so mould their peculiar features to comply with modern railroad conditions that their efficiency is no longer an experiment, but a positive accomplishment (see Fig. 12).

FRANKLIN INSTITUTE

QUALITY OF LIGHT.

BY

PAUL F. BAUDER.

[Popular Science Lecture, delivered at Witherspoon Hall, Friday evening, November 12, 1909.]

As various new illuminants have been placed upon the commercial market the question has arisen as to the relative value of the light given by them, as an artificial duplicate of daylight. Such a broad use of the term daylight has led to much discussion between the advocates of each artificial light source. It is the purpose of the author to submit results of some investigations upon which an estimate can be formed as to the comparative merits of each of the more common commercial illuminants.

None of the artificial sources of light which the author has investigated gives a quality of light which approximates that of daylight. However, the proper use of those which have been investigated, with a due consideration as to their defects, will tend to assist consumer and producer alike in the improvement of present systems of illumination.

The development of civilized man has taken place beneath the light of the sun. It would, therefore, appear that the standard of light for all purposes should be sunlight and all of the qualities of this light should apply to the ideal artificial illuminant. This would be the case if man were to labor chiefly out-of-doors as did his predecessors; but the requirements of civilization have been directed towards interior occupation. It is evident for this reason that any variation from an industry undertaken beneath the light of the sun might require a variation in the character of light to be used whether it be natural or artificial.

Daylight is the only natural light source, while under the heading "artificial illuminants" may be placed all of the light sources which have been in use since the beginning of time.

At best, daylight is greatly variable, but nevertheless it

has generally been the light to which artificial sources were referred. It is apparent that this light must have certain fundamental characteristics which make it a standard. A standard of illumination must, however, have certain requirements, the most important of which is constancy. There are so many varying conditions which affect the light from the sun that no definite standardization of average daylight has been universally agreed upon by investigators. Those qualities, for a standard unit of illumination, which mark the sun as the ideal illuminant for the majority of conditions may be classified under the following headings: *Intensity, Color value, Direction of rays, Ability to reveal detail, Adaptability.*

These five qualities will be discussed separately.

INTENSITY OF DAYLIGHT ILLUMINATION.

The sun is brightest at noon, *i.e.*, the sun is at its maximum intensity, when there is the smallest chance for its direct rays to enter the eye and injure the retina. The eye of man is naturally protected, by the projection of the forehead, from the high intensity of the sun's light during the larger portion of the day. At sunrise and sunset, however, the rays of light of maximum intensity come in a horizontal direction and are therefore more liable to injure the delicate interior of the eye. The usual presence of mist or fog and the greater absorption due to an additional depth of atmosphere at the horizon decreases the brilliancy and gives to the light a diffusion and color tone, which causes no injurious effect upon the eye. Although the principle of a light source varying to meet natural conditions cannot be applied to artificial illuminants, that of placing the light source above the range of vision, so that the natural construction of the eye may be utilized, is immediately appreciated.

The diffusion and reflection obtained in artificially lighted rooms are far different from the effects obtained with sunlight or daylight. The height of interiors limits man in employing to the best advantage the principle of diffusion in planning artificial illumination.

Actual sunlight which has been referred to is a quantity unknown upon the earth. The source of sunlight is distant from the surface it illuminates by more than eleven thousand

times the diameter of this surface. During the greater portion of the day about fifteen or twenty per cent. of the total light received from the sun is diffused daylight, scattered from finely divided particles suspended in the intervening space between sun and earth. If this atmospheric condition were not present, the sky would be dark and spaces to which the light rays were not directly admitted would likewise be dark.

The eye will adapt itself to great changes in the intensity of daylight. A similar relative percentage change in brightness of artificial light sources as now used would however be prohibitive. On account of the fact that the variation in intensity has but a slight effect upon the ease with which the average person can work under natural light, there must be some characteristic of daylight which under certain conditions will produce a much more marked effect upon the human eye than that previously mentioned. This fact is shown in many industries where the light used must be uniform in color value if not in intensity.

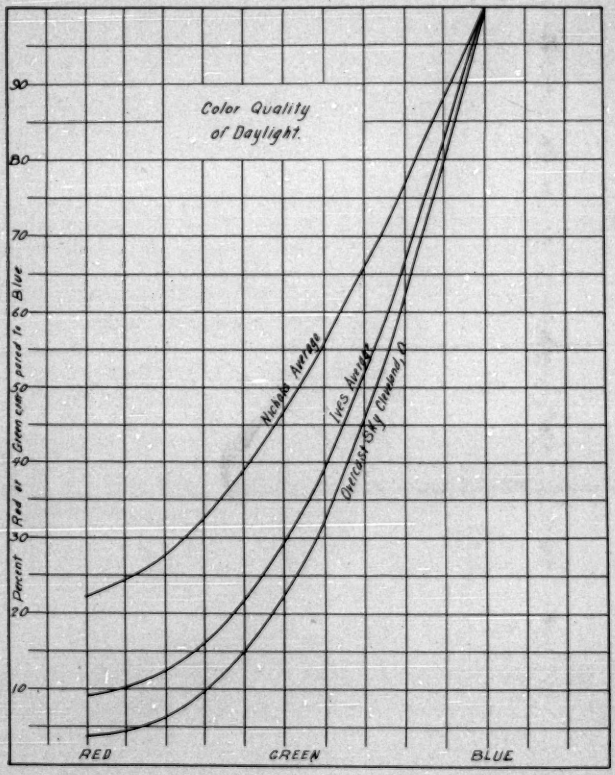
COLOR QUALITY OF DAYLIGHT.

Light is radiant energy which in the form of waves of different lengths affects the nerves composing the retina of the eye. These waves express themselves as different colors. Average daylight or so-called sunlight is a clearer and whiter light than that from any artificial lighting source thus far perfected. When allowed to fall upon a prism, however, it is immediately seen that this white light is composed of seven visible and easily distinguished colors, namely; red, orange, yellow, green, blue, indigo and violet in varying proportions. These colors are the seven fundamental or visible spectral colors which form a part of the total radiation from the sun. This wave radiation or emission from the sun affects the human sight only in that portion of the spectrum between the red and blue limits.

The so-called infra-red and ultra-violet extremes of the spectrum, which lie on either side of these values of red and blue, form the larger portion of the radiation from artificial sources and due to their wave lengths they are lost to view. It can readily be shown that the most efficient illuminant would be one in which all of the radiation properly proportioned as

to color would occur between the limits of red and blue and therefore would be visible.

FIG. 1.



Curves showing proportions of fundamental colors composing daylight.

Daylight is composed of varying proportions of the seven visible colors. The greatest variation in the quality of daylight may be attributed to the varying percentages of these funda-

mental colors. In all forms of daylight a certain relationship exists between its different component colors. A relation remaining practically the same under most conditions is that the amount of blue light in nature is maximum while the red is minimum. Such a relation of the fundamental colors can be likewise noted in all growths in which the reds are produced to a less degree while the blues and violets are always apparent. Other primary colors composing daylight vary in amount between the two limits. A similar statement is true for all forms of light radiation whether natural or artificial; in the latter, however, there does not exist the same proportion of fundamental colors as in any form of daylight.

Reference to the table will enable a fuller understanding of the percentages of the different fundamental colors composing the visible spectrum of daylight to be obtained.

"Nichols's"[1] results for per cent. of color in daylight—general averages:

	Wave lengths in cm.	Lower levels	Higher levels	All levels
Red	$.725 \times 10^{-4}$	5.12	4.14	4.53
Orange	.625	9.09	8.48	8.71
Yellow	.530	13.71	13.37	13.48
Green	.460	19.50	21.62	20.81
Blue	.420	24.46	26.90	26.08
Violet	$.390 \times 10^{-4}$	27.93	25.43	26.45

By exhaustive observation it has been found that any color of light can be duplicated by combining in various quantities three of the primary or spectral colors, namely, red, green and blue. In laboratory practice as well as commercially by the process of trichromatic photography, it is shown that color shades and tones can be correctly reproduced by the proper combination of these three instead of the seven colors. This principle has been embodied in an instrument invented by Mr. H. E. Ives, and called the "Ives's Colorimeter." It is an instrument which gives correct percentages of the three primary colors composing the light from any of the present incandescent light sources. In this apparatus, the three primary colors of light are combined by a so-called color mixing device and allowed to fall on one-half of the field in the instrument, the other half being illuminated by the source under test.

[1] Transactions Illuminating Engineering Society, May, 1908.

By regulating the proportion of the three colors, Dr. H. E. Ives of the Bureau of Standards has duplicated the color of average daylight and has likewise made accurate determinations by this method of the proportions of the three colors comprising the light from any artificial sources. His results are given in a paper presented before the Illuminating Engineering Society. Several other investigators, have likewise made measurements which show that the value of blue light composing the average daylight is much in excess of that obtained independently by Dr. Nichols and reduced to same basis as measurements made with colorimeter.

As previously stated, and as shown by the curves in Fig. 1, it is readily seen that the proportion of the three colors of light composing daylight is so variable that a standard for average daylight would be difficult to obtain. How variable this standard is, may be more readily appreciated if one compares a series of colors as seen in the light of a north window with the same colors as seen at a west window in the light of the late afternoon sun. Not only do the natural conditions of the atmosphere produce such great changes in the color value of light, but it must be recognized also that certain conditions affect this quality as much or more than atmospheric changes. The causes of variation in the color of daylight entering any space may be tabulated as follows:

CAUSES INVOLVING THE SKY ALONE.

1. Clear blue sky.
2. Cloudy sky.
3. Overcast sky.
4. Natural conditions due to rain or snow.
5. Natural conditions due to dust or suspended particles.
6. Artificial conditions due to smoke or chemical vapors.

CAUSES INVOLVING THE SURROUNDINGS.

1. Condition and color of surface of ground.
2. Trees, shrubbery, or gardens in proximity.
3. Walls of adjacent buildings.
4. Character of windows or openings for the admission of light.

The color quality of light which enters any given space may vary in any of the three fundamental colors composing it as much as twenty to thirty per cent., according to changeable conditions of atmosphere and surroundings. For this reason, it can readily be understood that a standard of daylight has not

yet been obtained to which artificial illuminants may satisfactorily be compared.

The variations which have been mentioned allow of enough changes to take place to make daylight of different qualities unserviceable for some classes of interior work. There are relatively few art studios and shops where articles of delicate color value are sold in which it is possible to make a proper comparison of colors on all occasions. This is due to the many varying conditions affecting the quality of daylight which enters.

It is apparent that more consideration should be given to this characteristic of daylight when it is compared with artificial illumination. Not only should this condition be taken into account in art galleries and other locations where the color of decorations plays an important part in making the sales, but it should also be considered in home interiors, offices and other places where the color plays an important part in the harmonious appearance of surroundings. For instance a man living in a city should be interested in the color which a neighbor paints his house, as it greatly affects the light received through his side windows. Decorative effects are greatly varied by the condition of the color of the surrounding buildings, etc., to such an extent that when the sun's light is reflected from a light colored surface such as a snow-covered ground or a white wall of a building, a flat indistinct appearance is given to interior effects. With an exterior ground surface of a soft color tone from which the light is reflected to an interior, the quality of light reflected produces a color effect which greatly improves the interior appearance.

DIRECTION OF RAYS OF LIGHT.

The directional relation of natural light plays a very important part in the general appearance of any surroundings. Maximum daylight is usually received in a plane approaching more nearly the vertical than the horizontal, causing shadows and high lights to appear in correct proportion.

On the other hand an extremely flat effect would be caused by a light with almost complete diffusion, caused in nature both by the presence of suspended dust particles, clouds and many reflections from surrounding objects. A very similar effect is produced when the difference between the lights and shades

is too highly accentuated as in the case of objects illuminated by a search-light.

It is seen from this that there is a necessity for directing light into such locations that there will be sufficient direct as well as diffused light to make a harmonious shading from high light to shadows without a marked change from one to the other. Shadows may be considered by some as unimportant, because it appears that a person can see almost as well in diffused sunlight, caused by clouds, as in direct sunlight.

On days when there is no direct sunlight there is considerable shadow but there is a less sharp contrast between light and shade because of the gradual character of the change. Were it not that shadows are always present, the work of the architect would not appear very artistic, particularly in exterior work. In interiors the numerous windows acting as light sources cause complex shadow effects, making the problem of illumination with the proper proportion of light and shades more difficult. The adoption, however, of the principle of taking exterior conditions into account, would, no doubt, have a marked effect.

Shadow depends upon direction of light. If the illumination of the lower, or less illuminated, portions of an object in daylight were interchanged with upper or more illuminated portions, the object would be almost unrecognizable and constitute a negative picture. Reverse the condition and it at once stands out in detail. With perfect diffusion, however, we would have none of this light and shadow effect, which make an object plainly visible.

ABILITY TO REVEAL DETAIL.

This question of having the proper direction of light in order to make objects visible, invisible, or of revealing detail, has a direct bearing on the question of visual acuity. The color value of light in making possible fine distinctions of detail plays a more or less important part in the physiological effect produced upon the eye. It is found in daylight that a person doing work which requires a proper consideration for fine lines and detail will not depend upon the direct light from the sun but will in all cases seek a diffused illumination. This may be obtained in a shadow or from a portion of the sky,

which is not the brightest. In reading a person will always prefer the light obtained from a window, which is not receiving direct rays of the sunlight unless a shade or curtain of some kind obstructs the direct rays and softens them in intensity and color value. It is true that different eyes are affected differently. Some require more light of one quality than others but in the majority of cases it must be noted that light, for proper purposes of reading or fine distinction, will be within certain limits of intensity and must likewise be of a certain quality and diffusion to allow the least possible direct light to enter the eyes of the observer.

In dealing with the subject of visual acuity or power of revealing detail, with lights of different color value, the effect of large light variation must be considered. Most commercial sources of light due to slight causes vary so greatly in their individual characteristic color quality that it is found necessary, in order to properly designate the best light for given purposes, to turn to the primary colors and note which is best.

Most persons find themselves short-sighted for the light from the blue and violet ends of the spectrum. Patterns, when illuminated by red, green and blue light show that for the power of revealing fine detail with an accompanying ease of sight, the blue and green lights are to be preferred to the red for short distances. The red, on the other hand, is preferred by the majority of persons for revealing details at a greater distance. Keeping this principle in mind, it can readily be seen what an unsatisfactory affect would be produced if a red or blue-violet light were to be used for general illumination purposes. The important requirement for a light is then to be able to distinguish color values, fine detail, etc., with the proper intensity and direction, whether it be daylight or artificial light.

The qualities of efficiency and steadiness of light production apply more directly to artificial sources of light than to that of daylight. These qualities may be grouped beneath the heading of adaptability, inasmuch as all light should be readily adaptable to meet various requirements.

ADAPTABILITY OF LIGHT.

The light from the sun was primarily used for purposes of mechanical labor where the necessity of revealing fine de-

tail, obtaining proper color quality, and intensity, were not required to such a great degree as they are at the present time.

On account of the requirements which have been developed in the progress of civilization, daylight has failed to answer for all purposes, due to the fact that our vocations must be pursued at all times without depending upon daylight. For this reason the adaptability of all sources of light, including both natural and artificial, must be given proper consideration.

It has been necessary to use prismatic glass and to adopt an entirely new construction of building and sky-lights, in order to use natural daylight for such classes of effort as are generally undertaken for manufacturing and industrial purposes. It is true that artificial illuminants must be adapted for more diverse purposes than daylight. They must likewise be directed in such a matter as to meet all interior requirements. Practically all commercial illuminants have been designed with this thought in mind. The ideal light source, on the other hand, must have such qualities of color and ability to reveal detail, such intensity and direction of maximum rays, as to make it capable in all conditions of service to meet certain requirements depending on the conditions surrounding the work for which they were intended.

Artificial Illuminants.—Having discussed the various characteristics of daylight in comparison to artificial light relative to the previously mentioned qualities, we shall make a few direct comparisons. The characteristic qualities of daylight will be compared with the similar qualities of the following illuminants in an endeavor to determine from the standpoint of adaptability which is the best for given conditions:

1. Carbon treated filament lamp.
2. Carbon untreated filament lamp.
3. Gem metallized filament lamp.
4. Tantalum filament lamp.
5. Tungsten filament lamp.
6. Nernst lamp.
7. Enclosed arc.
8. Upright gas arc.
9. Inverted gas arc.

The light flux of all these lamps was so different that no attempt was made to determine their candle-powers. The endeavor was made to obtain the actual effects of the quality

of light produced by these sources. The brilliancy of any of them is so far below that of the sun that the impossibility of obtaining comparisons in intensity between those and the sun is readily apparent.

In referring to the intensity of the light sources investigated, the advisability of placing a light source of high intrinsic brilliancy a sufficient height above the floor level of any space, in order to benefit by the principles previously noted regarding the sun, is self-evident. An alternative, likewise possible, is to reduce the intrinsic brilliancy of the source by using glassware of proper design and intensity to increase the diffusion of light and to decrease its brilliancy. By the use of this principle, the necessity of resorting entirely to height in order to produce a sufficient diffusion of light is eliminated.

The question of the color value of given commercial light sources is one which has caused more diverse opinions to be raised than any other quality of artificial illuminants. All artificial light sources have a characteristic quality of color which is apparent from observation. The colors of the illuminants investigated may be tabulated as follows:

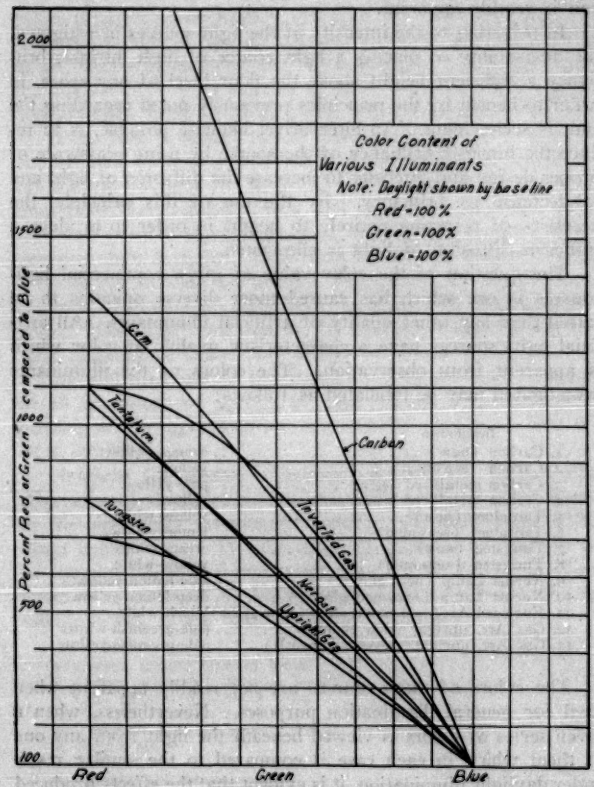
Designation	Color
1. Carbon (new)	orange-yellow.
2. Carbon (seasoned)	yellow.
3. Carbon metallized (new)	pale-yellow.
4. Carbon metallized (seasoned)	yellow.
5. Tantalum (new)	yellow-white.
6. Tantalum (seasoned)	lemon-yellow.
7. Tungsten (new)	cream-white.
8. Tungsten (seasoned)	yellow-white.
9. Nernst Lamp (new glower)	pale-lemon-yellow.
10. Nernst Lamp (seasoned glower)	deep-lemon-yellow.
11. Enclosed Arc (opal outer, clear inner globe)	bluish-white.
12. Gas Arc, upright (new mantle)	pale-greenish-white.
13. Gas Arc, upright (seasoned mantle)	pale-greenish-yellow.

The colors of these sources are not readily apparent when used for general illumination purposes. Nevertheless, when a given series of colors is viewed beneath the light from any one of them which in each case is compared to the similar result under daylight illumination, it is evident that the effects produced vary a great deal from the true color values as seen under daylight illumination.

Color photographs taken under constant conditions of exposure, intensity of illumination, and direction of light upon plates employing the principle of the Lumiere Auto-chrome proc-

ess of color photography show that none of the artificial light sources obtain results equal to the daylight effect, but the best

FIG. 2.



Color values of investigated illuminants as obtained by colorimeter.

of illuminants can be selected by the correctness with which they produce the daylight effect.

Another series of photographs, taken under similar conditions, show what a great effect the color quality of light has

upon interior decorations, the most delicate of which may be illustrated by the colors of natural flowers.

The colors which compose the given color of light from each of the various sources used for these photographs can be seen from the curves in Fig. 2.

The true importance of obtaining the best form of illuminant in order to give the most desirable and attractive results for all classes of service may be observed when a comparison is made between the color effects produced by carbon and tungsten illumination in comparison with that of daylight. The results show that a surprising advance has been made in the incandescent lamp industry in the endeavor to obtain a type of lighting unit which would cause objects to appear more nearly natural under artificial illumination.

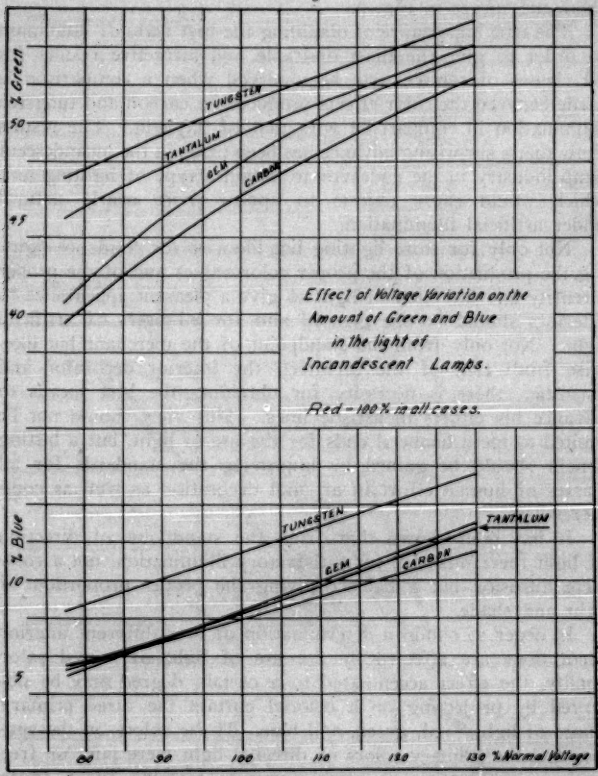
Not only for store lighting but likewise for residence lighting the production of the proper color values and of the proper intensity and direction of light to give a pleasant appearance to interiors should be the general aim for all users of artificial light. Not only from the standpoint of the merchant but likewise from that of the architect, the interior decorator and furnisher, there is necessity for obtaining the best means to advance his efforts in artistic lines. This view should not be limited to mere financial ends for the use of light, but a lasting benefit should be gained by improving the standards for all classes of human effort in art and decoration as well as commercialism.

It has been shown that from the standpoint of direction of light there must be, for satisfactory illumination, not a complete diffusion but a balance giving the proper proportion of light and shade.

In order to obtain a determination of how different interior decorations are affected by the use of light of varied color quality, the effect accentuated to a certain degree may be observed by projecting on a colored curtain the three primary colors of light—red, green, and blue. If the colors on the curtain and the primary colors of directed light were pure or free from a combination of color pigments forming them, those lines which were not illuminated by a light of a corresponding color quality, would appear black. This is easily appreciated; for the color which is seen, is only the impression received upon the retina of the eye by wave lengths of light which have

not been lost by absorption after falling on the colored surface. The necessity for obtaining a proper proportion of colors forming the light flux emitted from an ideal artificial light source,

FIG. 3.



Curves showing variation of the green and blue with a variation in voltage upon incandescent lamps.

whether alone or with the aid of glassware, is apparent. This proportion might not be that of daylight, but the colors composing the ideal light source should be such that there would

be an equal or equivalent percentage of each of the fundamental colors.

A question has arisen among the users of light as to the actual effect of raising or lowering the voltage impressed upon an incandescent lamp. In changing the intensity and especially the color value of such an illuminant. By means of the colorimeter the effect of voltage on green, and the effect of voltage on red (curves, Fig. 3) were taken with the red 100 per cent. in each case, to show what the variation in the green and red fundamental colors would be. The closer approach to the value obtained with the daylight value shown by the base line in each case of the tungsten lamp in comparison to the other incandescent light sources is very marked. Another detail not to be overlooked is that all of the electric incandescent lamps tend more nearly toward the daylight value as the voltage is increased above its normal value.

It is evident that the æsthetic tastes are sometimes appealed to by an incorrect use of illumination, in order to impress the observer with the beauty of surroundings. A more useful result would however be obtained by making the most practical efforts to impress the user of artificial light with the necessity for living and working to his best advantage under conditions requiring the use of artificial light. Owing to the inability of natural light to meet our modern requirements for constancy of intensity, color value, etc., it is obvious that artificial light sources correctly applied must be adopted.

It has been shown that some of the investigated sources are better for one condition of service than are others and it must be concluded that the best artificial illuminant upon the commercial market at present is that which is adaptable to the largest number of classes of service, providing that it maintains a high standard of the afore-mentioned qualities of light.

The importance of obtaining the best possible illumination can be better appreciated when it is considered that, at the present time as never before, there is in the minds of most people a broader comprehension of what constitutes good illumination. The five qualities of the ideal lighting source should not be overlooked, for many thousands of dollars are spent annually on the production of pleasing lighting effects. If these can be improved and the art of illumination placed upon a higher plane, we are effecting material progress.

SECTIONS

(Abstracts of Proceedings of Stated Meetings.)

Section of Photography and Microscopy.—Regular meeting held in the Lecture Room of the Institute on January 27, 1910, at 8 P.M. Dr. Henry Leffmann, President of the Section, in the Chair. J. W. Ridpath, Secretary of the meeting. Eighty-five members and visitors were present.

The room looked unusually cheerful and inviting, owing to the installation of a new system of lighting.

The reading of the minutes was dispensed with, and the Chairman introduced Mr. Charles Pancoast, of the Photographic Society of Philadelphia, who in a very pleasing manner, delivered an instructive lecture upon the Making of Lantern Slides. He preferred the use of artificial light because of its easy control and advised the novice to confine himself to one make of plate, and to one formula and strength of developer, varying his exposure according to the density of the negative, which should be sharp and full of detail. The lecture was illustrated by many excellent and beautiful slides, some of which were hand-colored.

Dr. Leffmann exhibited one slide, showing a section of granite, photographed with a color-screen, excluding the yellow and orange rays of light.

Mr. L. Koch exhibited eleven miscellaneous slides, some being colored, to show what an amateur with limited facilities could do.

The subject was discussed by Dr. Leffmann, E. H. Sanborn, and others.

The thanks of the section were extended to Mr. Pancoast.

At 9.20 P.M. the meeting adjourned.

J. W. RIDPATH,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held Thursday, February 3, 1910, at eight o'clock in the evening. Present, 55 members and visitors. In the absence of the Chairman, Dr. E. Goldsmith called the meeting to order. The minutes of the previous meeting were read and approved. The Chairman then introduced Mr. Samuel Lichtman, who read an interesting paper on "Modern Heavy Guns." The subject was illustrated by lantern slides, projectiles, powders, fuses, etc. After brief discussion a vote of thanks was tendered the speaker and the meeting adjourned.

ALFRED RIGLING,
Acting Secretary.

Electrical Section.—A stated meeting of the Electrical Section was held on February 10, 1910. President, Thomas Spencer, in the Chair.

The regular business of the meeting was transacted and a paper on "Electric Heating," illustrated by Mr. W. S. Hadaway, Jr., of the Westinghouse Electric and Manufacturing Co., Pittsburg, Pa., was delivered.

The remarks of the speaker dealt with the progress made in design of electric heating equipments and showed the tendency towards making direct application of the heat units to the work and brought out strongly the simplicity with which various equipments could be designed and constructed. Historical sketch of the progress in electric heating was also mentioned.

The paper was referred to the Committee on Publication and a vote of thanks tendered the speaker.

There being no further business, the meeting adjourned.

RICHARD L. BINDER,
Secretary.

A meeting of the Electrical Section was held February 17, 1910, at eight o'clock in the evening. Present, 43 members and visitors. Mr. Thomas Spencer in the Chair. After the reading of the minutes, the Chairman introduced Mr. Carl P. Nachod, who read a paper on "Electric Railway Signals." The subject was illustrated by means of lantern slides and a working model. After a general review of railway signaling, the speaker described the system of the Nachod Signal Company, which is designed for electric railways. At the close of the address a vote of thanks was extended to the speaker for his paper and the subject was referred to the Committee on Publications.

ALFRED RIGLING,
Acting Secretary.

Section of Photography and Microscopy.—Stated meeting held February 24, 1910, at eight o'clock this evening. Dr. Henry Leffmann in the Chair. Present, about 50 members and visitors.

The first contribution of the evening was a five-minute address on "Photographic Developers," by Mr. John Bartlett, Editor of the *Bulletin of Photography*. This was followed by two communications from Mr. Reuben Haines, relating his experience with various kinds of developers.

The programme then provided for a series of remarks by persons selected for the purpose and the subject was afterward open for general discussion.

Mr. Alfred Holden was the first of these speakers. He gave briefly his experience, of 35 years, with the various kinds of developers as they appeared in the market, and described the ways in which he used them and with which he had gotten the best and most satisfactory results, his preference for most work being *pyro*.

Dr. Leffmann spoke on the various kinds of developers, especially the recently introduced coal-tar products, and some of his experiences with them; the recent discoveries in color photography and some of his experiments in this line.

Röntgen-ray photography and developers were discussed by Mr. H. Clyde Snook and Mr. Alfred Holden.

Mr. S. Hudson Chapman spoke of the development of moving picture films and other negatives.

The following gentlemen took part in the general discussion: Messrs. Leffmann, Bartlett, Holden, Snook, Ridpath, Chapman, and others.

The meeting adjourned at 8.50 P.M.

J. W. RIDPATH,
Secretary.

NEW USE FOR AN OLD GUN.

With a view to standardizing explosive compounds, such as dynamite for example, the technological branch of the United States Geological Survey has recently been making some ingenious experiments. The most important feature of the contrivance employed for the purpose is a big mortar, formerly in use in the fortifications defending New York Harbor, at Sandy Hook. The explosive is set off in the mortar, which is suspended from above on a huge knife-edge. The shock of the discharge causes the gun to swing and the distance through which it sways is accurately measured by an automatic device, determining the energy developed. (*Technical World Magazine.*)

FRANKLIN INSTITUTE

(*Proceedings of stated meeting, held Wednesday evening, February 16, 1910.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 16, 1910.

President WALTON CLARK *in the Chair.*

The stated meeting of the Institute was held this evening at eight o'clock. The minutes of the previous meeting were read and approved.

Additions to membership since last report, 3.

The report of the tellers indicated that 138 votes were cast on the question of the amendments to the By-Laws; of these 132 were in favor of the proposed changes. The amendments were therefore declared adopted.

The President announced the following standing committees for the current year:

Committee on Library.—Edwin S. Balch, W. H. Gartley, Richard W. Gilpin, Lewis M. Haupt, H. F. Keller, Henry Leffmann, Louis E. Levy, Edward S. Miles, C. E. Ronaldson, Geo. F. Stradling.

Committee on Meetings.—James S. Rogers, James Christie, Kern Dodge, J. Logan Fitts, Lewis M. Haupt, Coleman Sellers, Washington Jones, J. Y. McConnell, Paul Thompson, W. J. Williams.

Committee on Museum.—A. E. Outerbridge, Jr., William H. Thorne, A. A. Blair, F. A. Genth, Jr., W. H. Greene, Edwin J. Houston, E. V. d'Invilliers, Arthur J. Rowland, George A. Hoadley, L. F. Rondinella.

The paper of the evening was presented by Mr. Grafton Greenough on the "Development of the Mallet Locomotive" and was fully illustrated by lantern slides. At the close of the address a vote of thanks was tendered the speaker and the subject was referred for publication. Adjourned.

JAMES CHRISTIE,
Secretary.

NATURAL GAS IN ONTARIO.

CANADIAN TOWNS UTILIZING IT FOR LIGHT AND FUEL.

On November 1 natural gas was turned into the mains and service pipes of the Windsor Gas Company, which before had been used to supply the city with artificial gas. The natural gas is piped from the Tilbury fields, 40 miles northeast of the city. Only the gas used for illuminating is purified, and this is done by individual purifiers placed on the premises of each consumer. For fuel the gas is used in its natural state. With few exceptions this gas will be used by the people for fuel purposes, but its use is not so general for illuminating, many preferring, even at greater cost, electricity for this purpose. The price charged for natural gas is 25 cents in the winter and 30 cents in the summer months per 1000 feet. Experts declare that developments in this field show a supply that can not be exhausted in less than twenty years. (*Consular Report.*)

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract from proceedings of the stated meeting held Wednesday, February 2, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 2, 1910.

MR. J. Y. MCCONNELL *in the Chair.*

The following reports were presented for final action:

(No. 2464.) Rushton Trailing Truck for Locomotives. (Adopted, Longstreth Award.)

(No. 2473.) The Underwood Typewriter. (Adopted, Elliott Cresson Award.)

R.

MINUTE ON THE DEATH OF PROF. MASCART.

The Board of Managers of the Franklin Institute takes cognizance of the demise of

PROFESSEUR ELEUTHÈRE ÉLIE NICOLAS MASCART

an Honorary Member of this Institute to whose varied and indefatigable labors the world is indebted for a large extension of our knowledge of the Physical Sciences and of their application in the several branches of Optics, Electricity and Meteorology. His researches in spectroscopic phenomena, dating almost from the inception of that science, greatly furthered its advancement and his investigations of meteorologic phenomena contributed data of permanent importance.

Professor Mascart's services in the determination of electrical units, from the beginning of the international movement for that purpose at the Congress of Electricity at the Paris Exposition of 1881, through all its subsequent developments at the Congresses in Paris in 1884 and 1889; in Chicago in 1893; Paris, 1900; and St. Louis in 1904, have permanently linked this name with the progress of electrical science and it was

Resolved, That the Board enters this minute in its records as a tribute to the memory of an honored member of the Institute and that the same be published in the JOURNAL.

BOOK NOTICES

SUMMARY OF ALLOYS—THE EMPLOYMENT OF PHYSICAL CHEMISTRY IN METALLOGRAPHIE. By Dr. Ernst Jänecke. 39 pages 10¼ x 7¼ inches, 20 illustrations. Hanover, 1909.

It is only of comparatively recent date that the study of metallic alloys has been pursued by rational methods that permit a satisfactory analysis of the more complicated metallic solutions. The author's purpose in compiling this summary is to present the latest progress in the art and to collect as completely as possible a bibliography of the latest investigations. L. E. P.

LA THÉORIE DES COURANTS ALTERNATIFS. Par Alexandre Russell, M.A., M.I.E.E., Traduit de l'Anglais par G. Séligman-Lui, ancien élève de l'École Polytechnique. Inspecteur général des Télégraphes. Volume i, 551 pages, 9 x 6 inches, 209 figures. Price, paper, 18 francs. Gauthier-Villars, Paris, 1910.

The first volume treating the theoretical elements was noticed in the November issue. The second completes this extensive study by a detailed account of the many applications in practical service of alternating currents, the problems involved and the methods and apparatus used in this increasingly useful method of distributing electrical energy. L. E. P.

CONGRÈS INTERNATIONAL DES APPLICATIONS DE L'ELECTRICITÉ MARSEILLE, 1908. Three volumes 9 x 6 inches, paper, edited by H. Armagnat. Part I, Rapports Preliminaires, vi + 709 pages, with many figures. Price, paper 24 francs. Part II, Rapports Preliminaires, iv + 784 pages with many figures. Price, paper 24 francs. Part III, Organization du Congrès, iv + 550 pages with figures and plates. Price, paper 20 francs. The set of three volumes, paper, price 60 francs.

The Commissioners General of the Electrical Exposition, held at Marseilles in 1908, in deciding upon the character of a congress for the convening of which the exposition offered a most fitting occasion, were mindful that previous international congresses, since the one in Paris in 1881, had favored questions of theory rather than those of practice. They accordingly, decided to devote the discussions of the congress to industrial and economic applications of electricity.

The first two volumes contain no less than fifty distinct papers upon the commercial applications of electricity, among which may be mentioned,—crossings for electric power lines; accidents from transmission lines and means of educating the public with view to their prevention; insulators; construction of transmission lines; electric traction; electro-chemistry. The third volume contains an account of the organization of the congress and its rules and a number of supplementary papers discussing the topics presented in the previous volumes.

The number, diversity, and character of these papers constitute a most valuable contribution on recent practice and progress in electrical engineering. L. E. P.

CURRENT TOPICS

WAVE vs. SHIP. Time was, not so very long ago, when the sea was undisputed master of the ship and whenever Neptune saw fit to send his league-long rollers across the deep, the proudest ship of the day must needs stop at his bidding, if she did not indeed turn and run before the fury of the blast. Of late years man has so multiplied horsepower and has applied so many ingenious contrivances for speed and strength and safety that Neptune must have foreseen the humiliating day when he could no longer hold the destinies of the bold sea voyager in his hand and no longer say to him "Thus far, and thus slowly shalt thou go."

It was reserved for the steam turbine to supply the last mechanical device which was to give man the complete victory in his age-long struggle with the elements. In the combination of size and strength and power afforded by the latest turbine liners there has been developed a ship with the ability to drive at full speed and all day long into the heaviest seas that the stormy North Atlantic could pile across her path.

Some two winters ago the "Lusitania" in weather which varied from a gale to a full hurricane averaged for 24 hours a speed between 26 and 27 land miles an hour. During that tremendous struggle ten-ton anchors were shifted and steel derrick booms were swung athwart-ship and twisted as if they were no stouter than a boy's tin whistle. Yet the ship steamed into port practically intact and with not a rivet started in the whole fabric of her hull.

On the night in question the glass windows in the pilot-house had been lowered, and the storm windows of solid wood, with a small, heavy glass port-light in the centre, had been raised. The stern of the vessel was lifting high on a receding sea, and the forecastle was awash, when a wave of gigantic proportions loomed up at the bow. This wave must have been some 35 feet high measured from the trough. The ship was running at half speed and met the sea with a speed of from 12 to 13 knots. When the mass struck the breastworks and pilot-house, every one of the stout wooden storm windows was burst in, and the heavy steel framing between the windows was forced several inches into the pilot-house. The quarter-master was borne back against the bulkhead behind, carrying in his hands the wheel which was torn from its standard. At least 4000 tons of water must have been swept over the fore-castle deck, and the momentum was sufficient to crush the fore-castle deck and the three decks below a few inches down into

the body of the ship, leaving them with a permanent set. Evidence of the enormous stresses to which the ship was subjected is afforded by the stanchions and solid steel bulkheads below the deck, which buckled out of the vertical as they yielded beneath the load above. We are inclined to agree with her captain that many smaller and less stoutly built ships, which have disappeared utterly at sea, may have been sent to the bottom by the crushing in of their decks under so-called "tidal-waves" of these dimensions. (*Sci. Am.*, Jan. 29, 1910.)

A THUNDERSTORM OBSERVATORY has been established in Spain by Señor G. J. de Guillen Garcia in which atmospheric discharges, both local and distant, are detected graphically and acoustically. A wireless telegraph instrument is used for this purpose, because each lightning discharge is accompanied by electro-magnetic waves similar to those used in wireless telegraphy. If there is a storm anywhere within a radius of 500 miles, the observer is notified by the recording instrument. As all barometric depressions that pass over Western Europe come from the Atlantic Ocean, the new observatory gives meteorologists due warning of the approaching disturbance. By noting the intensity of the sounds produced in the receiver and observing whether they grow more distinct or less, it is possible to determine the approximate course of the storm. (*Sci. Am.*, Jan. 29, 1910.)

THE INVESTIGATION OF THE SPECTRA of the planets, which was begun at Lowell Observatory in 1902, has been continued. V. M. Slipher found a combination of dyes which renders the sensitiveness of the commercial dry plate fairly uniform into the red as far as to wave-length 7000, beyond which point it drops rapidly, but is sufficient at A to record that line faintly in the prismatic Solar spectrum. With the aid of this plate, the spectra of Jupiter, Saturn, Uranus and Neptune have now been photographed with greater extension into the red than any previous photographic or visual observations, and a number of lines and bands have been discovered. (*Sci. Am.*, Jan. 29, 1910.)

AN ELECTRICALLY HEATED HOUSE. At a recent meeting of the N. Y. Electrical Society one of the speakers referred to a certain house that had been designed to be heated and lighted by electricity alone. The house contains no chimneys, stoves or coal storage room, and the saving in these requirements of the usual coal-heating system was sufficient to pay for the entire electrical installation. In regions where coal is dear and water power plentiful, electric heating and lighting is no doubt more economical than coal heating. (*Sci. Am.*, Jan. 29, 1910.)

THE MOON AND RADIO-ACTIVITY. M. Paul Besson made experiments in the summer of 1908 and 1909 which showed that the variation in the activity of mineral water varied with the atmospheric pressure, being highest when the pressure lowered. Other observers have noted the same fact. But he noticed other variations which were unaccounted for, and thought they might be due to the tidal movement of the earth's crust. The author's observations lead to the following conclusions: As regards atmospheric pressure alone, for a one hour's test which is constant with relation to the moon's passage at the meridian, and thus excluding the moon's influence, the radio-activity increases when the atmospheric pressure decreases. As to the influence of the moon, he finds that at a constant barometric pressure, the activity is maximum for the passage of the moon at the meridian and minimum for the passage at the other side. Should it be found that the moon's movement caused changes in the radio-activity of the air, we would have the proof that the moon has an influence on the changes of the weather, according to the popular belief, this being caused by multiplying or lessening the centres of condensation of water vapor, outside of air pressure effects and others. (*Sci. Am.*, Jan. 29, 1910.)

MONEL METAL CASTINGS. The making of monel metal castings is now past the experimental stage and is being successfully accomplished in at least three foundries in New York and New Jersey. This non-corrosive alloy was recently introduced by the Orford Copper Co. Its composition is approximately 68 per cent. nickel, 1.5 per cent. iron and the remainder copper, these being the proportions in which the elements exist in the ore. On account of the large proportion of copper it was unprofitable to work the ore for the production of nickel, but it was discovered that the smelted but unrefined metal gave an alloy of considerable value. It is tough and strong, much the same as nickel in appearance, with a softer and more attractive color.

It has been used extensively for sheets. The first success in making castings was made by Isaac G. Johnson & Co. at Spuyten Duyvil, N. Y. They produce boat propeller wheels, rudders, centre-boards, deck fittings, water ends of pumps, linings, valves, plumbing fixtures, shafts, piston-rods, valve stands, crank-shafts, pipe connections, forgings and so forth. (*Iron Age*, Jan. 20, 1910.)

THE NEW YORK AUTOMOBILE SHOWS. From the two annual automobile shows, one held at the Grand Central Palace and the other in Madison Square Garden, it is evident that automobile design and construction have become practically standardized. The most prominent changes in the 1910 models

were more luxurious bodies, refinements in the details of mechanism tending to higher efficiency, the use of longer chassis and larger wheels.

It has been predicted that automobiles would become cheaper as the number of manufacturers increased. This prophecy has been partially fulfilled, but it would appear that substantial, reliable machines have nearly reached the minimum limit of cost. The cheapest car at the Palace show was $485, at the Garden show the Flanders runabout was $750. The highest priced cars were $6500 at the Palace show and $7500 at the Garden. This year most makers have somewhat advanced their prices, but there is generally a more complete equipment furnished, such as a magneto, gas tank, gas lamp, rumble seat, larger tires or a more powerful motor.

The Torpedo body is one of the newer types. This form lessens the wind resistance, raises less dust, and affords greater comfort particularly through the longer wheel base now generally provided. The largest car was a Thomas, carrying eight passengers. Numerous cars carrying five, six and seven passengers were on exhibition. More commercial vehicles were shown than ever before, the largest being of five tons capacity.

The American-La France Fire Engine Co. of Elmira, N. Y., exhibited a heavy commercial truck to which the Manly hydraulic transmission has been applied. The essential features are a pump with three radiating cylinders driven directly by the engine and two motors of similar construction to drive the two rear wheels. The motors and pump are connected by a closed circulating piping system, the discharge from the pump being passed through the motors and returned. The pump is arranged to give variable stroke, so that running at constant rotative speed, the volume of its discharge may be varied from zero to maximum, giving corresponding speeds to the motors and in either direction. With the pump set to give no discharge the motors are positively held and constitute in themselves the brake. In addition to the steering wheel there is but one lever with which the operator is concerned; this gives variable speeds, forward and reverse, with a continuous range, *i.e.*, not by steps. When the speed is set at zero the machine is held even on a very considerable incline. The importance of such a simple control on a heavy truck can hardly be exaggerated, as an ordinary truck driver and not necessarily a trained chauffeur is competent to handle it.

As compared with foreign makes, American cars are conspicuous for the absence of sloping bonnets. The construction of the frames is of steel of channel sections and the frames are heavier and stiffer than in previous years. Many of the makers are furnishing wheels with demountable rims, so that spare tires may be carried inflated and substituted for punctured ones

very quickly without deflating. Several furnish detachable tires as well as demountable rims. (*Iron Age*, Jan. 20, 1910.)

THE LIBRARY OF THE ASSYRIAN KING, SARDANAPALUS. During the past fifty years twenty thousand stone tablets, approximately, of the library of Sardanapalus, the Assyrian King, were found in the excavations among the ruins of Nineveh and taken to London. The texts written on them, which are apparently related to one another, are now published in their original cuneiform script by the British Museum in serial collections. Various savants of the whole world have therefore an opportunity for further investigation of the texts relating to their special province. In the fourteenth collection are assembled those tablets which regard chiefly the objects of the three natural kingdoms. Obviously many of these lists were prepared for purposes of medication.

For this reason a prominent physician, Baron Oefele, assisted by noted scholars in cuneiform script, among them Prof. Zimmern of Leipzig, examined this collection. Apart from the many lists which mention minerals, the numerous lists of animals are mostly of a uniform kind. The names of animals are arranged in two columns, the first column in Sumerian and the second column in Accadian, *i.e.*, in Babylonian.

Far more interesting than the zoölogical lists are the botanical lists, which are very numerous, and which give the most various directions to acquaint the aspiring physician with the effect and use of hundreds of medicinal plants. This fact may suffice to show that among the old Babylonians the knowledge of the natural sciences was already far greater than among their successors, the Greeks and the Romans, whose names for animals and plants, it is manifest, have been derived partly from the Babylonian language. (*Sci. Am.*, Feb. 5, 1910.)

TUNGSTEN-STEEL BAR. A German manufacturer states, in *Stahl und Eisen*, that he has succeeded in making satisfactory high-speed steels with powdered ferro-tungsten. The steel contains 0.85 per cent. of tungsten, 0.45 per cent. silicon, 0.45 per cent. manganese, 0.30 per cent. carbon, 0.25 per cent. aluminum, calcium and magnesium, and 0.01 per cent. sulphur. The powdered ferro-tungsten alloys more readily than tungsten metal, and there is less segregation and piping. (*Sci. Am.*, Feb. 5, 1910.)

THE HOYT MULTI-CIRCUIT VOLTMETRE. This voltmetre is constructed on the D'Arsonal principle, dependent on the fact that a permanent magnet furnishes a strong magnetic field within the poles of which a coil, centrally pivoted and

acting against a spring control, is rotated by an electric current passed through its windings.

The improvements claimed in these instruments are: that the pole pieces are formed in heavy, specially constructed dies, securing mechanical uniformity at a low cost; and the magnet and pole pieces are supported on a one-piece, die-formed angle plate which also secures the complete system to the containing case, and assures a rigidity that cannot be equalled by any other means.

This method of support is unique. The pivots are securely riveted to the inner surface of the aluminum frame on which the wire is wound, and specially designed screws, carrying the jewels, are recessed into the iron core around which the coil rotates. Thus the coil rests on the top jewel, and is centrally guided by the bottom jewel. A metal finger carrying one end of the controlling spring is securely attached to the outside surface of the aluminum frame, and upon this is wound the wire which carries the current. The other end of the controlling spring is attached to an arm insulated from the plate which supports the pole pieces.

By means of this construction zero errors can be readily corrected without any danger of changing the adjustment of the bearings. This voltmetre is made in two sizes, the six-inch with a capacity of six, and the eight-inch for fourteen lamps. They are also made in pocket, portable and switchboard styles. (*The Metal Industry* of Dec., 1909.)

A METALLIC ALLOY, as a solder for aluminum has been patented by Gaza Hartmann, assignor to Hartmann Aluminum Solder Co., New York.

This alloy contains tin, aluminum, nickel and metallic magnesium, and the best result is obtained when metals of the quality known in the arts as pure are mixed in the following proportions:

Tin	800
Aluminum	170
Nickel	7
Magnesium	23
	1000

(*The Metal Industry* of Dec., 1909.)

AN EXPERIMENTAL ROAD has been constructed at Truro, which it is claimed has the merits of being resilient, mud and dust proof, noiseless, and requires no removal of the old surface. It is made by spiking down on the roadway sheets of expanded steel, similar to those so largely used for the rein-

forcement of concrete, and laying over them, to a depth of two inches, ordinary road material treated with coal tar, and rolling well in. (*Sci. Am.*, Feb. 5, 1910.)

ELECTRIC POWER is furnished to Helsingöre, Denmark, from Sweden by a cable under the narrow sea separating the two countries. The power is generated at a 300 ft. fall of the river Laga in Sweden, and is conducted to the coast by a cable which connects with a submarine cable three miles long. The transmission of power by means of a submarine cable is quite unusual. (*Sci. Am.*, Feb. 5, 1910.)

TITANIUM ARC, by W. S. Weedon. Of a large number of substances examined as to their suitability for arc-lamp electrodes, none was found to give so high an efficiency in candle power per watt as materials containing titanium. A titanium flame arc can be produced by using a titanium carbide cathode and a copper anode. To prepare the electrodes, finely powdered titanium carbide is mixed to a plastic mass with oil or glycerin and then extruded through a nozzle. The sticks thus obtained are cut into suitable lengths, dried first at the ordinary temperature and then in a gas oven, then fired at a high temperature in a carbon tube electric furnace. The temperature must not be too high or the finished electrodes may be brittle. The arc is usually produced with direct current, but under certain conditions, alternating current may be employed. The efficiency of the arc increases with increase of current density and of the length of the arc. With an arc length of 1 inch and a current of 3 ampères at 103 volts, 0.228 watt is consumed per horizontal candle power. At 2.87 ampères and 95 volts the power consumption is 0.51 watt per mean spherical candle-power, and 0.37 watt per mean hemi-spherical candle-power. The arcs are operated most satisfactorily on a constant current circuit rather than on a low-voltage multiple circuit. A titanium arc may also be produced with a cathode of titanium suboxide produced by the reduction of rutile in an electric furnace. The character of the arc is almost identical with that of the arc produced with titanium carbide, but the efficiency is higher and the light much steadier. There are, however, the disadvantages that large troublesome deposits are liable to be formed on the anode, and that the titanium suboxide cathode is consumed fairly rapidly. The titanium suboxide can be operated with the direct current only. (*Electro-Chemical and Metal Industry.*)

SULPHURIC ACID FROM GYPSUM. Gypsum is readily decomposed when intimately mixed with sand or silica and strongly heated, a mixture of sulphur dioxide, oxygen and

water being evolved; the small proportion of iron oxide in ordinary or sea sand acts catalytically and hastens decomposition. From the gases evolved sulphuric acid may be obtained by the contact process, and from the purity of the product and the fact that the residue may be utilized for making glass, it is considered that gypsum could possibly compete as a raw material for sulphuric acid manufacture in localities where gypsum is plentiful but pyrites scarce. (*Journal of the Society of Chem. Industry.*)

TEST FOR FUMING SULPHURIC ACID. The old method of testing by titrating with a normal alkali solution is not considered satisfactory for regular technical use by the foreman of an acid works, because a very slight error in the strength of the solution or in the quantities of the materials used causes a serious error in the percentage of free sulphuric anhydride. Unless titrations are made by the chemist it was extremely difficult to get concordant results. As it is not practicable to have the chemist on hand day and night, and as control analyses have to be made once an hour on several kinds of acid, it is most important to have a simple and reliable method. The principle involved in this new method is the measurement of the heat developed by combining the free sulphuric anhydride with water. As this heat value is very great, very small variations in the percentage of free anhydride make large variations in the heat produced. To eliminate as far as possible the heat of dilution of sulphuric acid, I prefer to take as the source of water for hydrating the anhydride, a sulphuric acid of such concentration, that when a given quantity is mixed with an equal weight of fuming acid, the resulting mixture will contain only slightly more water than is necessary to produce the monohydrate. In practice, when a fuming acid of 20 per cent. to 25 per cent. of free anhydride is to be tested, I use for mixing with it a sulphuric acid containing 92 per cent. of H_2SO_4. The analysis must be done in a vessel so arranged as to prevent the loss of heat by radiation. A Dewar vacuum tube is most satisfactory. When using one of these tubes the drop in temperature through radiation does not materially affect the result within the time required for analysis. In detail the method of procedure is as follows:

One hundred grammes of the fuming acid are weighed into a Dewar's vacuum tube. The temperature (*a*) is noted, and then the temperature (*b*) of the reagent acid, after which 100 Gm. of the 92 per cent. acid are poured into the Dewar tube and thoroughly mixed by stirring with the fuming acid already in the tube. The temperature (*c*) of the mixture is recorded. The heat of reaction equals $c-\frac{a+b}{2}$, making no allowance

for the heat capacity of the tube. In order to avoid corrections for the heat capacity, or any other small errors which might creep in, tests are made in this manner of fuming acids, the composition of which is exactly known, and from these initial determinations a table is prepared.

Heat of Reaction, °F.	Free Sulphuric Anhydride, °F.	Heat of Reaction, °F.	Free Sulphuric Anhydride, °F.
72.0	21.0	87.6	23.6
73.2	21.2	88.8	23.8
74.4	21.4	90.0	24.0
75.6	21.6	91.2	24.2
76.8	21.8	92.4	24.4
78.0	22.0	93.6	24.6
79.2	22.2	94.8	24.8
80.4	22.4	96.0	25.0
81.6	22.6	97.2	25.2
82.8	22.8	98.4	25.4
84.0	23.0	99.6	25.6
85.2	23.2	100.8	25.8
86.4	23.4	102.0	26.0

This table shows a difference of 6° F. for each per cent. increase of free anhydride, and as the readings may be depended upon to within ½° F. the results obtained are extremely accurate. Any intelligent workman can carry them out and the time required does not exceed 3 or 4 minutes.

Test of monohydrate. The same principle may be used to give a most accurate determination of the strength of sulphuric acid from 95 per cent. to 100 per cent. H_2SO_4, but of course in making the test the fuming acid must be used in excess, and the heat developed is the measure of the uncombined water contained in the sulphuric acid to be tested.

The reagent used is ordinary fuming acid of 24 per cent. to 25 per cent. anhydride, and with this fuming acid a sulphuric acid containing from 94 per cent. to 100 per cent. H_2SO_4 may be tested.

The temperature (a) is noted of 100 Gms. of acid to be tested; the temperature (b) of 100 Gms. of the fuming reagent acid is recorded, and this added to the monohydrate and thoroughly mixed. The temperature (c) of the mixture noted. The heat of reaction equals $C—\frac{a+b}{2}$. As before, all allowances for corrections are obviated by preparing a table from tests of acids of known composition, which may be seen in the original article.

It may be noted that for every 0.1 per cent. variation in the acid between 94 per cent. and 100 per cent. H_2SO_4 there is more than 1° F. difference in the temperature. This method can be extended to cover a great variety of compounds. ("The

Heat of Chemical Reactions as a Basis for a New Analytical Method," by Henry Howard, in *Journal of the Society of Chemical Industry*, Jan. 15, 1910.)

PRICE OF RADIUM. The Austrian Ministry of Public Works is trying to settle upon a place where radium may be sold and the price to be charged. The question arose when a quantity of ore shipped from Joachimsthal was found to contain no less than one gramme of radium. The price for this small quantity has been fixed at 380 crowns ($77.14) per milligramme. Those who contemplate purchasing radium may have their addresses entered at the Ministry of Public Works in order to receive information as to quantities and current prices of radium. (*Sci. Am.*, Feb. 5, 1910.)

DR. E. G. ACHESON was presented with the Perkin medal at a recent meeting of the Chemists' Club. He received the medal for discovering entirely new materials suitable for many purposes and now indispensable to the world, such as carborundum, deflocculated graphite and Egyptianized clay. (*Sci. Am.*, Feb. 5, 1910.)

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